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THESIS

**An Automated Reconnaissance and Surveillance
Planning Tool**

by

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September 1992

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An Automated Reconnaissance and Surveillance Planning Tool

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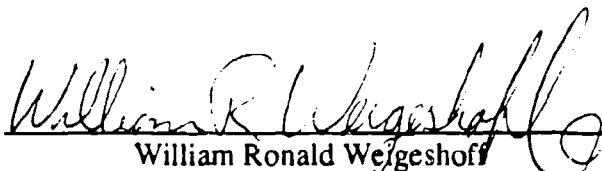
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ABSTRACT

The Automated Reconnaissance and Surveillance (R&S) Planning Tool is a prototype of the Army's proposed Common Ground Station, and serves as an Intelligence interface to NPSNET. This system incorporates Intelligence Preparation of the Battlefield (IPB) and intelligence asset modeling in order to create realistic intelligence collection.

IPB is the analysis of the effects of the terrain, weather, and enemy doctrine on the friendly situation. Intelligence System Modeling is performed for Mounted and Dismounted Scouts, Ground Surveillance Radars (GSR), Joint Surveillance and Attack Radar System (JSTARS), and Remotely Piloted Vehicles (RPV). These systems' collection effort can be monitored by displaying their individual perspectives of the battlefield, or their combined collection effort can be plotted on a 2D or 3D representation of the Terrain. The raw intelligence data produced by these systems is analyzed according to the number and types of enemy vehicles located. Probable enemy courses of action are also generated. Automated R&S planning can greatly enhance the already lethal capability of the Army by speeding up the Collection and Dissemination Process.

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I. INTRODUCTION

A. PURPOSE

The purpose of this research is to develop a system that serves as an intelligence interface for Naval Postgraduate School's Combat Simulator (NPSNET) and that doubles as a simulator and trainer for the Army's Common Ground Station (CGS). The Reconnaissance and Surveillance Planning Tool attempts to model the proposed Common Ground Station interface and uses techniques to refine combat information into intelligence. This system is capable of playing the intelligence collection, processing, and dissemination play for NPSNET and in turn serve as a simulator and trainer for CGS.

B. BACKGROUND

Reconnaissance and Surveillance, (R&S), planning is a tedious process requiring numerous man hours. The planning process is continuous. It changes as the enemy and friendly situations change. R&S planning revolves around two subproducts: List of intelligence systems available and Intelligence Preparation of the Battlefield (IPB). These subproducts change over time causing the R&S Plan to also change.

1. IPB Process

The IPB product is a graphical representation of the terrain, weather, enemy and friendly tactical situation at a particular point in time. Each aspect of the IPB is looked at individually and together in order to develop a picture as to how one or more affects the other. The methods used to analyze these affects come from the acronym "OCOKA" [FM 34-130].

a. O - Observation and Fields of Fire

Observation involves the influence of terrain on reconnaissance, surveillance, and target acquisition capabilities. In the IPB context, it refers to optical and electronic Line of Sight (LOS). Fields of Fire involve the effects of terrain on weapons

effectiveness. The effectiveness of direct fire weapons is heavily influenced by the terrain within the target area. These weapons require LOS to the target.

b. C - Cover and Concealment

Concealment is protection from air and ground observation. Cover is protection from fire. Concealment is vital for operational security and deception. Both are vital for protection from hostile fire.

c. O - Obstacles

Obstacles are natural and man-made terrain features that stop, impede, or divert military movement. The impact of obstacles on mobility make them an important consideration during the terrain analysis.

d. K - Key Terrain

Key terrain is any feature or area the seizure or control of which offers a marked tactical advantage. Any terrain that increases or decreases the capability of either the enemy or friendly forces to apply combat power may be key terrain. The same is true for terrain which permits or denies maneuver.

e. A - Avenues of Approach and Mobility Corridors

Avenues of approach are routes by which a force may reach key terrain or an objective. Avenues of approach are evaluated according to their maneuver support potential, access to key terrain or adjacent avenues of approach, degree of canalization, cover and concealment, observation and fields of fire, and obstacles. Mobility corridors are areas which permit movement and maneuver. They permit friendly and enemy forces to advance or withdraw in doctrinal configurations, and to capitalize on the principals of mass, shock, momentum, and speed.

Traditionally these effects have been portrayed on numerous sheets of acetate, and one by one laid over a paper map. This manual process of analyzing the effects of "OCOKA" is prone to errors. Errors will be reduced by automating the intelligence

collection and dissemination process. Automation will also allow plans, overlays, and maps to be stored in computer memory and referenced or changed at any time.

2. Collection Asset Management

Monitoring which intelligence assets are available, for querying and tasking is also a difficult task. Some assets are more precise than others. Some are more timely, and some just are not capable of collecting the required information. Managing intelligence assets often proves overwhelming for the inexperienced and experienced alike. Intelligence assets range from soldiers on the ground to satellites in space. The big question is always, "Which system can best collect the desired information and how is it tasked?"

3. Real World Application (CGS)

The Gulf War, Desert Storm, has helped the Army recognize a need to automate intelligence collection. During the war, information that battlefield commanders needed was usually known by someone. The people who had the information did not know who needed it nor were there methods for disseminating the information to the appropriate battlefield commanders. This is unsatisfactory, and needs to be fixed.

The Army's answer to the intelligence collection and dissemination problem is Common Ground Station (CGS). CGS is a computer that functions as a common interface and processor for combat information collected by all sensors [O&O PLAN]. A form of CGS will be located at every echelon, brigade and above, and will communicate together creating network of Common Ground Stations. Units then could task, disseminate and request information with ease. The overall objective of CGS is to speed up and enhance the intelligence collection and dissemination process.

The dynamics of R&S Planning lends to the automation of the process. The "Automated Reconnaissance and Surveillance Planning Tool" can speed up the preparation of the IPB product by automatically generating the Modified Combined Obstacle Overlay (MCOO). Automation can make IPB more accurate than current methods. It can also make the management of collection assets easier.

4. Battlefield Simulation Application (NPSNET)

The Computer Science Department at the Naval Postgraduate School, Monterey CA, can also benefit from the CGS concept. The Computer Science Department is building a battlefield simulator similar to the Army's battlefield simulator (SIMNET). The research is called NPSNET [ZYDA 92]. NPSNET uses the Silicon Graphics family of computers in creating an interactive battlefield simulator. NPSNET models the interactive play of the mover and shooter of the battlefield, but does not incorporate intelligence play. Players see the whole battlefield to include the locations of all enemy and friendly forces. By adding a CGS type environment, fighters only know what they see or what their intelligence assets report.

C. PREVIOUS WORK

There has been previous work performed by many companies over the last seven years on display and analysis of digital terrain data. Among those applications is the "Digital Cartographic Applications" produced by Grumman Data Systems for the Rome Laboratory, Air Force Systems Command [GRUM 89]. This system is designed to work as a graphical interface for many strategic systems such as Joint Surveillance and Attack Radar System (JSTARS), All Source Analysis System (ASAS), and others. This application analyzes all of the terrain characteristics necessary for an informative 2D map display on which the results of these systems can be superimposed.

Fairchild Defense's "Fairchild Common Mapping Tool (CMT)" is another geographic display software package [FAIR 91]. This system performs functions similar to the Grumman Data Systems product. CMT also includes the integration of the Global Positioning System (GPS) for navigation assistance. CMT has been used by Maryland's Montgomery County Police Department. Both systems virtually eliminate the need for paper maps at the planning level.

The product these systems produce is similar to the IPB portion of this research. They do not provide for real-time 3D representation terrain representation that could be useful in seeing the terrain without being there.

D. ORGANIZATION

This thesis is subdivided into eight chapters. Chapter I is a general introduction of terms, keywords, phrases, and previous work in the area of this research. Chapter II introduces Reconnaissance and Surveillance Planning in detail. Chapters III and IV discuss applications of the Reconnaissance and Surveillance Planning Tool to "Near Real Time" intelligence systems such as CGS, and intelligence training on a battlefield simulator like NPSNET. The two and three dimensional graphics and the expert systems used in the Reconnaissance and Surveillance Planning Tool are discussed in Chapters V, VI, and VII. Finally, Chapter VIII discusses future work in automating intelligence collection planning and dissemination. The appendices include a Users Manual that describes the specifics of how the Automated Reconnaissance and Surveillance and Planning Tool works and how it is organized to run on the Silicon Graphics family of computers, and a sample data file used by Enemy Situation and Analysis Expert System.

II. AUTOMATED RECONNAISSANCE AND SURVEILLANCE PLANNING

A. INTRODUCTION

The objective of reconnaissance and surveillance planning is to collect information required by the commander to fight and win battles. The required information usually includes: terrain trafficability, weather conditions for at least the next 24 hours, night illumination data, and the current enemy situation. Illumination and weather data are relatively easy to obtain, and therefore are not discussed in this paper. Terrain trafficability and the enemy situation are a more difficult problem and are discussed in detail.

1. Terrain

Historically terrain data has come on paper maps, covered in contour lines, symbols, colors, and print. A legend at the bottom of the map assists the user in reading the map. It explains what the symbols, and colors mean. Information about the geolocation of the map and the contour lines is also provided. A general description of these terms is necessary for understanding.[FM 21-26]

The contour lines represent elevations, and reliefs at almost every point on the ground. The spacing of contour lines gives an indication of the slope of the terrain at a given location, and whether or not the terrain is trafficable. Contour lines also give the only clue as to what the terrain looks like.

Colors are used on paper maps to identify vegetation, built up areas, water, roads, borders, as well as other geographical characteristics. Color intensity gives an indication of density. Dark green means dense vegetation, while darker red indicates dense areas of habitation, or high quality roads. Lighter colors mean these items are less dense. Colors and color intensity provide vital information about the terrain and trafficability.

The print and symbols give the mathematical and literal interpretations of the map. For example, grid lines help a person identify his geolocation with a particular

accuracy, and names of cities, rivers, and countries give cultural information as well as geographic information. Words and symbols often identify what a particular building's purpose is: such as a school, or a court house. With print and symbols, a person can learn to read a map quickly.

Combining information from contour line, symbols, color, and print, a commander attempts to assess the affects of the terrain on his operation. Most of the time the method used provides only an estimate. Intelligence personnel never have the time to measure the distance between contour lines at every point on the map and in all directions to determine whether a piece of terrain is trafficable. Printed maps that depict trafficability exist but are rare. Hence, the trafficability overlays are only as good as the effort put into them, and trafficable terrain is often mismarked. Unfortunately, most commanders believe what they see, and many have been defeated because the enemy attacked from where the commander thought he could not.

Another vital characteristic of paramount importance is intervisibility lines. These lines can not be depicted on a paper map. Intervisibility lines indicate whether or not something at a particular location can be seen from another location[WINN 89]. It is accessed by selecting a location on the map to look from and performing a line of sight (LOS) analysis from that point out a desired distance. This is done at varying elevations above the terrain or at ground level. Not being able to identify intervisibility lines usually means the difference between life and death on the modern battlefield. This is unacceptable with todays' technology.

The Automated Reconnaissance and Surveillance Planning Tool has the capability to evaluate the trafficability and intervisibility of terrain thoroughly and expeditiously. Its only limitation is accuracy of the digital map. Digital terrain maps come in varying degrees of resolution[FM 21-26]. Terrain maps with one meter resolution are best, but maps with a 100 meter resolutions may be acceptable in some situations. A computer can analyze the elevations of a one meter resolution terrain map for trafficability

based on the slope of the terrain. Terrain is then colored according to whether the terrain is not trafficable (NO GO), moderately trafficable (SLOW GO), or trafficable (GO) terrain.

Digitized overlays such as vegetation, waterways, soil composition, urban areas, and transportation networks can be analyzed in a similar fashion. For example, NO GO or SLOW GO terrain that has been modified for a highway is reshaded as GO terrain, or a high-speed avenue of approach crossed by a dense minefield is turned into SLOW GO. Vegetation, cities, water, and other features slow, impede, or improve trafficability. A computer has the capability to make these adjustments quickly. Digitized overlays eliminate the need for piles of acetate overlays, which decay in quality over a short amount of time. The Automated Reconnaissance and Surveillance and Planning Tool is capable of reading, analyzing, and displaying a 100 meter resolution digital elevation map that covers a 54 X 45 KM map in under 5 seconds, on the Silicon Graphics IRIS 4D/240VGX computer. The digital map can be colored a number of different ways, depending on the desired information. Overlays are added for additional information.

Commanders will be more accurately informed about the trafficability and intervisibility of the terrain by letting a computer analyze and provide the terrain information almost instantaneously. The Automated R&S Planning Tool improves a commander's ability to make informed decisions about the terrain quickly and improves his chances of winning on the battlefield.

2. Enemy Situation

In order for a commander to be successful, he must not only know the terrain but also the enemy. Unfortunately the enemy of today is difficult to define. The threat an enemy force projects is relative to its cause and resources, and our national interest [TRADOC Pam 525-5B]. The Department of Defense breaks these threats and the wars they rage into three categories: Low Intensity, Mid Intensity, and High Intensity Conflicts. The threats also vary in organization, equipment, and doctrine. World powers produce their own weapons, and organize based on experience, and fight according to their doctrine. Smaller

nations tend to adopt the organization, and doctrine of their world power allies. The job of a commander and his intelligence staff is to know the enemy. How is he equipped? How is he organized? How will he fight? How is he defeated?

Depicting the enemy situation on a map is only the first step. Trying to figure out what the enemy will probably do is the hard part. Probable courses of action are developed from the enemy situation template. These courses of action can be as simple as (Will the threat attack, or will he defend?) or more complex. For simplicity purposes, this tool tries to answer the attack or defend question. The automated R&S Planning Tool assumes all enemy forces are equipped with Soviet made weapons and use Soviet organization and doctrine. A more robust tool could incorporate many different weapons, organizations, and doctrines.

3. Collection Assets

An essential part of R&S planning is knowing what assets are available and capable of collecting the information required to fight and win on the battlefield. Sources of information run from the scouts on the ground to satellites in space (Figure 1).

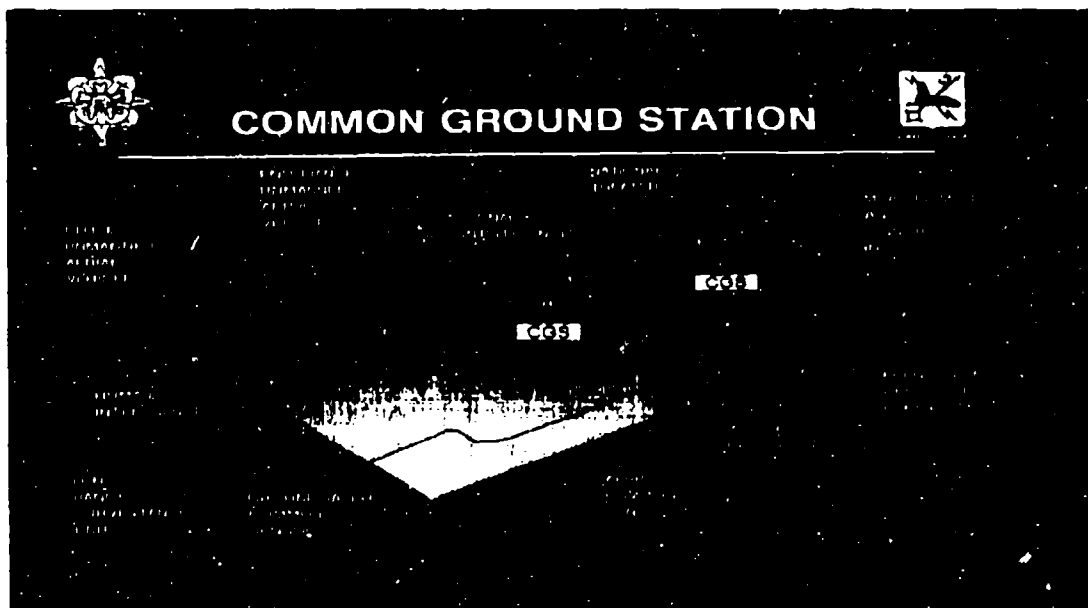


Figure 1: CGS Collection Assets [O&O PLAN]

Some are better at collecting and disseminating information than others. For the purposes of this thesis, Scouts, GSR's, RPV's, and JSTARS are the only systems addressed. These are only a few of the collection assets actually available, but they represent a wide variety of capabilities.

a. *SCOUTS*

Scouts are human beings equipped with binoculars, video cameras, and other vision assisting aids. They have an average effective range of 3 KM for identifying threat forces depending on the terrain. They are mounted or dismounted, and just about every unit owns some. Mounted Scouts are traditionally referred to as "SCOUTS" while dismounted scouts are referred to as "OP's". The advantage of SCOUTS and OP's is they are directly tasked and report directly to their own unit. The disadvantage of scouts is they do not always see well in the dark and they are not expendable.

b. *GSR's (Ground Surveillance Radar)*

GSR's are intelligence collection assets that can identify and locate moving target within their range. They have an average range of 10 KM for identifying and locating moving vehicles, and 3 KM for locating walking soldiers. GSR's are an effective day and night collection asset, and are abundant.

c. *RPV's (Remotely Piloted Vehicle)*

RPV's are remotely piloted vehicles that are equipped with video cameras. They are capable of flying over enemy forces and confirming their composition and location. These systems are small and hard to destroy. Unfortunately they are not yet abundant, and information must be requested from the owning unit. This makes the utilization and flexibility of this asset hard.

d. JSTARS (Joint Surveillance and Attack Radar System)

JSTARS is a nationally owned system that is similar to a GSR in functionality. JSTARS is an airplane that identifies and locates moving targets over a large area. Since this is a national asset, brigades will seldom reap the benefits of its capabilities.

e. CGS (Common Ground Station)

CGS is not an intelligence collection asset. However, it is an important new improvement in intelligence collection. The current method of collection and dissemination of information from systems not personally owned is a difficult and time consuming process. CGS fixes this deficiency. All units that own a CGS will receive reports from all of these assets directly (Figure 2).

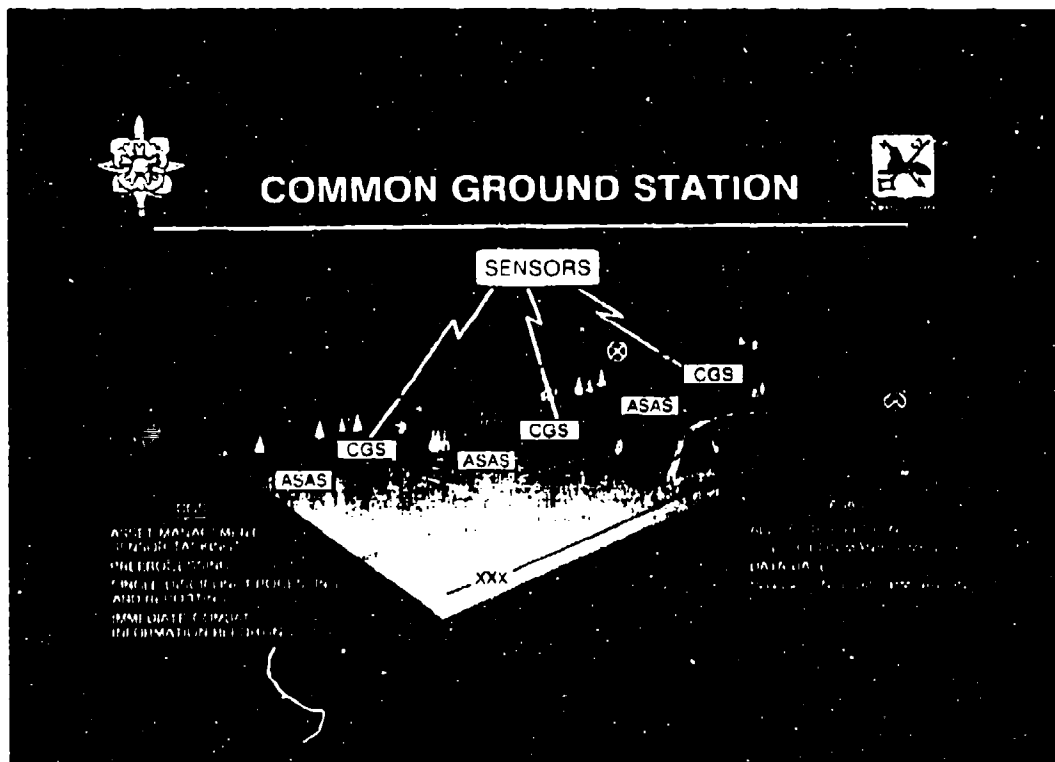


Figure 2: CGS Network [O&O PLAN]

B. INTELLIGENCE PREPARATION OF THE BATTLEFIELD (IPB)

IPB is the analysis of the affects of the terrain, weather, and enemy doctrine based of the friendly situation. This process must be completed prior to creating an R&S Plan. IPB encompasses terrain analysis, weather analysis, and a means for analyzing enemy probable courses of action[FM 34-130]. The R&S Planning tool uses Defense Mapping Agency's, (DMA) digital map data for slope, elevation, surface, and obstacle analysis. Weather is not directly addressed in this thesis but its effects on the terrain are inferred through the use of the surface, elevation, and slope data. Enemy doctrine is evaluated according to how the threat is organized. The IPB in this thesis is abbreviated but still useful. The phases of the IPB shown in Figure 3.

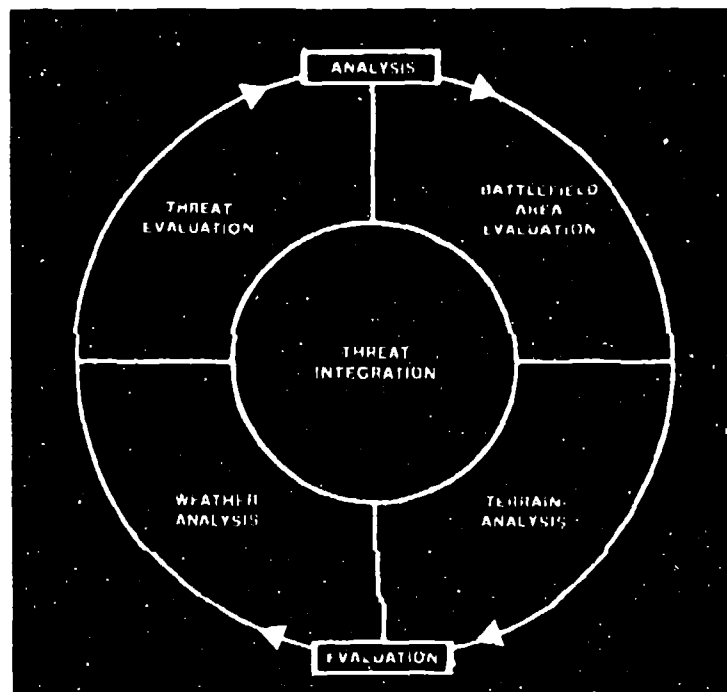


Figure 3: IPB Process [FM 34-130]

1. Terrain and Weather Analysis

The function of terrain analysis is to reduce the uncertainties regarding the effects of natural and man-made terrain on military operations. Vegetation, surface

material, surface drainage, surface configuration, obstacles, cross-country mobility, and lines of communications are all incorporated in the terrain analysis.

Weather analysis considers the effects of wind speed and direction, visibility, and precipitation on military operations. In this thesis, weather analysis is not be addressed. The slope, elevation, and water networks, are analyzed in this thesis to determine the affects of precipitation on cross-country mobility. The final product of the terrain analysis is the production of the Modified Combined Obstacle Overlay (MCOO).[FM 34-130]

2. Threat Evaluation and Doctrinal Templating

Threat evaluation is the detailed study of enemy forces, their composition and organization, tactical doctrine and weapons. Threat evaluation determines the enemies capabilities and limitations and how he fight if not constrained by the terrain. Threat evaluation is the initial templating performed when little or nothing is known about the enemy.

3. Threat Integration

Threat integration is the integration of the threat and the terrain. Threat integration is usually accomplished through the development of the Situation, Event, and Decision Support templates. The Situation template depicts the most current information known about the enemy, as well as doctrinally templated forces yet to be confirmed on the map. The Event and Decision Support templates are a means for evaluating future maneuvers of the enemy forces and how they affect our plans. The event and decision support templates take the enemy and the terrain into account.

Doctrinal templates may place enemy forces on untrafficable terrain, while the event and decision support templates must place the enemy on appropriate terrain. Trafficable terrain is then subdivided according to what size units it can support. These trafficable areas are called mobility corridors. The introduction of mobilities allows intelligence personnel to focus on where the enemy can travel.

Mobility Corridors can be analyzed in order to assign meaning to areas of interest. These areas of interest are called Named Area of Interest (NAI's), Mobility Corridors, Avenues of Approach, Objectives, Decision Points (DP's), Reconnaissance Routes, and Targeted Areas of Interest (TAI's). These areas of interest can be developed from the terrain analysis and a little knowledge about the threat.

NAI's, TAI's, and DP's are areas that concern battlefield commanders enough that they dedicate resources to watch them. Avenues of Approach and Recon Routes can be drawn within mobility corridors in order to assign offense and defensive meaning to the mobility corridors. These key areas of the battlefield form the basis for preparing R&S Plans.

C. INTELLIGENCE SYSTEMS MANAGEMENT

Intelligence System Modeling is performed for mounted and dismounted Scouts, GSR's, JSTARS, and RPV's. These systems can be given missions to execute. Their collection effort can be monitored directly by displaying their perspective of the battlefield on the computer monitor or their combined collection effort can be plotted on a 2D or 3D representation of the terrain. The raw collected data is analyzed according to the number, types, and location of enemy vehicles. Probable enemy courses of actions can be developed from this the processed information.

D. SUMMARY

Reconnaissance and surveillance planning is a cyclic process that involves knowing the terrain, enemy, and your own capabilities. When the process is started little or nothing is known about the enemy or his exact whereabouts. Plans are crude but are not developed in the dark. Information is known about the terrain, and enemy doctrine, therefore educated plans can be developed, and more information can be gained. At later stages, the battlefield becomes better defined. The information desired becomes more specific. Knowing which collection asset is best for the job is essential. The bottom line is, commanders rely on timely information obtained through R&S Planning.

With current technology and automation a commander can be more informed than ever. The Automated Reconnaissance and Surveillance Planning Tool is the first step toward providing timely battlefield information. It generates an automated IPB, reducing mistakes caused by the manual method. It provides for a means for developing informed R&S plans. It plots the geographical locations of enemy and friendly forces based on maneuver plans, and intelligence reports. Finally, it processes the intelligence reports through a crude parser to determine probable course of action. This thesis is a first generation tool for providing this information. Future systems can be developed to perform more complex operations.

III. COMMONGROUND STATION (Real World Application)

A. INTRODUCTION

The Army named its first generation reconnaissance and surveillance planning tool Common Ground Station (CGS). CGS is an automated system that gives the battlefield commanders near real time information on the terrain, and enemy situation. [O&O PLAN] The stand alone system is designed to take raw data from some intelligence collection platforms, and semi processed data from others. The stand alone CGS processes the data and provides the battlefield commander with the most information in the shortest amount of time. The biggest problem with intelligence collection is not collecting the information, but rather providing the information to every one who needs it, in the form they need it. Commanders at different echelons and locations need different information. The difference is in scope. Additionally, commanders are seldom satisfied with the amount of intelligence they receive. They always want to know where the information came from, and how that information was obtained. This allows the commander to assign the information a level of credibility. Unfortunately, sources are often highly classified. CGS eliminates much of this controversy. If a commander wishes to see a piece of information, he will have the ability to view a report, photograph, or video directly from his common ground station. The name of the source is removed to protect its identity.

It is the Army's proposal that every unit, Brigade and above, have a common ground station in its headquarters [O&O PLAN]. All of the CGS's can be used as a stand alone system or networked to provide for information sharing. Through information sharing, a brigade commander has access to information collected by divisions, corps, army, and perhaps, national level systems (Figure 4). This means the battlefield commander can see the battlefield from many different perspectives, giving him the best information available to fight and win on the modern battlefield.

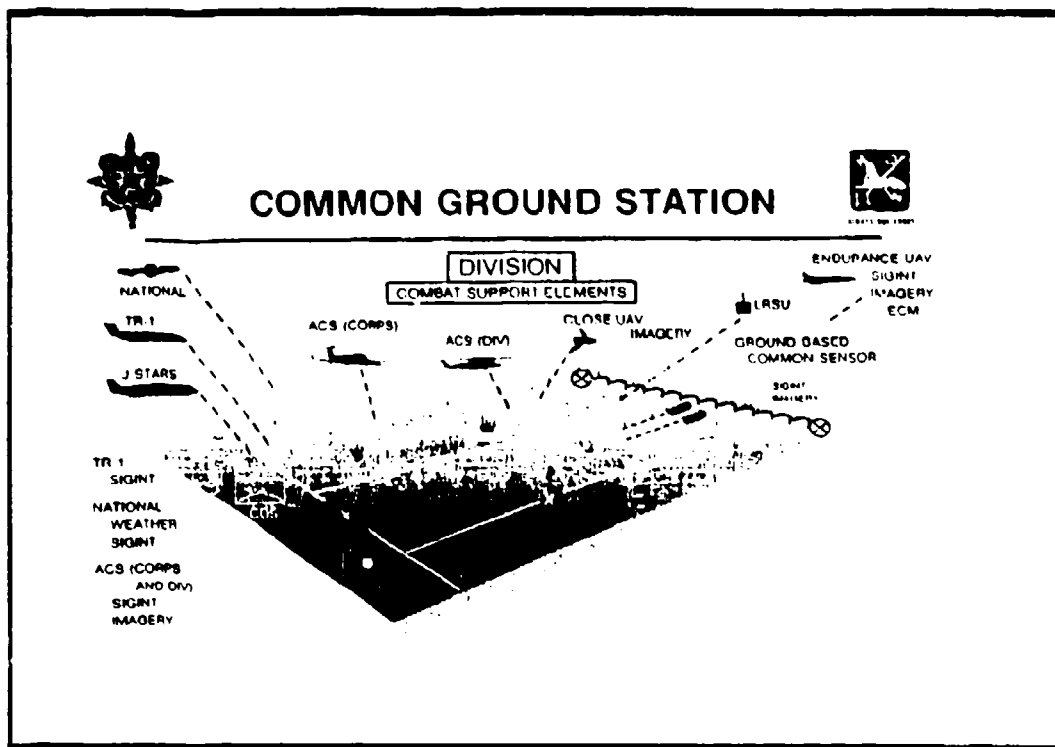


Figure 4: Conceptual Drawing of CGS [O&O PLAN]

B. CGS PROTOTYPE

The motivation behind this thesis is to attempt to build a computer simulated prototype of a common ground station using Silicon Graphics Inc. Computers, digitized terrain data, and threat force simulations provided by NPSNET. This system could be used with simulated data for training, or with real data as a CGS. The Automated Reconnaissance and Surveillance and Planning Tool can, in principle, simulate the functions of a common ground station. The Automated R&S Tool provides for terrain analysis, as well as, reconnaissance system modeling and battlefield monitoring, and threat simulation. An efficient terrain analysis can display any map that has been digitized by elevation and provide information on trafficability. Mounted and dismounted scouts, ground surveillance radars (GSR), remote piloted vehicles (RPV), and JSTARS are modeled simulating the

ability to manage information provided by reconnaissance systems from a multitude of echelons. And, in the absence of real data, simulated data can be used for threat replication.

The selected reconnaissance systems represent a cross-section of real time collection assets. Mounted and dismounted scouts represent a human intelligence (HUMINT) asset, Ground Surveillance Radars, and JSTARS represent electromagnetic intelligence systems (ELINT), and remote RPV's represent a video (IMINT) down-link capability. A video link has also been simulated for mounted and dismounted scouts as a proposal for future systems.

Scouts traditionally provide spot reports on what they see. These reports can be formatted, digitized, and sent via a data burst transmission to the controlling headquarter's CGS to be processed and displayed. Raw data from ELINT sources can be sent directly to a CGS and displayed as Moving Target Indicators (MTI's), and video links are simulated using 3D terrain rendering.

This thesis assumes one station controls all of these assets. In reality information sharing between CGS's would be required in order to collect some of this information.

C. COMING OF AGE

Automation advances have made building a low cost Common Ground Station a viable option to replace the more archaic intelligence collection methods currently used. Paper maps, huge books, and big staffs can be reduced through the introduction of automated intelligence planning, collection, and dissemination. The automation of intelligence collection can provide informative pictures, and quick access to information otherwise impossible to obtain in a timely fashion. Success on future battlefields dictates the necessity for a system capable of planning, collecting, and disseminating battlefield information in near real time, to every one who needs it, when they need it, and in the form they need it. Common Ground Station is the Army's answer.

IV. NPSNET (Training for the Real World)

A. INTRODUCTION

NPSNET is a Naval Postgraduates School research project that looks into battlefield simulation. Research has focused on making NPSNET be a low cost battlefield simulator. NPSNET is implemented on inexpensive Silicon Graphics Work Stations[ZYDA 92].

NPSNET is a real-time, interactive, 3D visual simulation system capable of displaying, real terrain, man-made and natural obstacles, as well as combat vehicles. NPSNET attempts to physically model each object displayed, according to its specific physical properties. A higher level functionality of NPSNET is semi-automated forces. What NPSNET lacks is an intelligence interface.

A player on NPSNET knows the location of every vehicle on the battlefield. The enemy and friendly situations are known by all players. Hence it does not simulate the uncertainties associated with actual battlefields. The Automated Reconnaissance and Surveillance and Planning Tool provides a portion of those uncertainties, known as the "FOG OF WAR". Battles can be won or lost based on a unit's ability to effectively collect intelligence. Intelligence personnel should therefore be considered an integral part of any battlefield simulator.

B. TRAINING INTELLIGENCE OFFICERS

Training personnel in the art of intelligence planning, collection and dissemination given the variety of intelligence collection assets is a difficult process. The Army's All Source Intelligence Officer is a product of the current techniques used. There are few places an all source intelligence officer can go where he uses assets from all echelons to build an "All Source Picture" of the battlefield. Common Ground Station will provide him with information, from all sources, Human Intelligence (HUMINT), Electromagnetic

Intelligence (ELINT), Imagery Intelligence(IMINT), and others, in order to build an all source picture during a war, but there are no training devices for CGS.

C. NPSNET FOR TRAINING

By using the Automated R&S Planning Tool as the front end to CGS, as well as an intelligence interface to NPSNET, means those training on NPSNET would at the same time be training to work on a CGS.

The Automated R&S Planning Tool provides realistic training for all source intelligence personnel. When implemented into NPSNET, intelligence plans can be created and tested against semi-automated forces. The effectiveness of one plan can be compared to another and critiqued. The training can take place on a variety of places and against different scenarios. Intelligence persons can learn from their mistakes as well as build contingency plans prior to risking actual human lives in a real war.

Training is an essential part of fighting. NPSNET and the R&S Planning Tool can provide a low cost training environment for intelligence personnel, and make simulated battles more realistic for the fighters.

V. 2D GRAPHICS AND MAPS

A. INTRODUCTION

The presentation and analysis of intelligence information is currently performed on paper maps with acetate overlay. Each overlay contains information about the terrain and enemy, or a combination of both. An average intelligence section at a brigade headquarters will produce and maintain an order of 10 to 20 overlays. Collecting and storing enough maps for missions that cover miles of terrain and producing overlays for each is a difficult task and often a duplication of effort. These overlays are produced by almost every unit in the army, and it is likely that two overlays portraying the same information look significantly different. Maps and terrain overlays that do not change significantly over time should be produced only one time and distributed. Incorporating DMA's digital map products will reduce the duplication of effort and will ensure a quality product.

Defense Mapping Agency's (DMA) Standard Production Format, Digitized Terrain Elevation Data (DTED) and Digitized Feature Analysis Data (DFAD) [DFAD 86] are used in this research. DTED is equivalent to a paper map without vegetation, cities, roads and other overlays. DFAD is equivalent to all the feature overlays such as rivers, roads, cities, soil composition and others. R&S overlays are generated on top of the DTED and DFAD data, resulting in the development of an informed R&S plan.

The 2D graphical display for the Automated Reconnaissance and Surveillance Planning Tool is composed of three primary objects:

- The Digital Map (Produced through DTED Data)
- Digital Overlays (DFAD and R&S)
- Iconic Vehicles (Reconnaissance, Friendly and Enemy Combatants)

Many operations are performed on the objects in the 2D display (Figure 5). Maps are switched or colored in order to provide a particular piece of information. Areas of the map can be isolated through the use of a "ZOOM" feature. Icon images of the reconnaissance vehicles can be maneuvered through the terrain. Finally, overlays can be partially or

completely displayed. These operations make the 2D display informative and flexible. The Silicon Graphics Inc. (SGI) family of computers has a built-in graphics library and special hardware that makes the rendering of the terrain and overlays, and vehicles quick and efficient in the 2D display.



Figure 5: 2D Map

B. DIGITAL MAPS

1. Map Resolution

DTED forms the basis for generating and displaying informative information about the terrain. A DTED map of the terrain model is first loaded into the R&S Planning Tool during the preprocessing phase of the program. The elevations are loaded into a two dimensional array indexed by integers representing the latitude and longitude of each elevation. The elevation array format appears in the Equation 5.1.

$$\text{ELEVATION_MAP [LAT] [LONG]} = \text{elevation} \quad (\text{Eq 5.1})$$

DTED data comes in two resolutions. DTED Level 1 has a resolution of 3 arc seconds or about 100 meters, and DTED Level 2 has a resolution of 1 arc second or about 33 meters, [DTED 86]. One meter resolution provides the best view of the terrain when analyzing the shape and slope. However, one meter resolution takes more time to analyze than a 100 meter resolution map. The difference in time is due to the number of elevation points involved.

- 1 Meter Resolution- 100,000 elevation points / 100 Meters square
- 5 Meter Resolution - 400 elevation points / 100 Meters square
- 100 Meter Resolution - 4 elevation points / 100 Meters square

The trade off is quality of information versus time. In order to analyze a one meter resolution map covering 50 X 50 Km's, the computer would have to make calculations based on 25×10^{12} elevation points. A 100 meter resolution of the same map would require calculations based on 2500 elevation points. For the purposes of this research only 100 meter resolution was available and used. The largest map size used in this research is approximately 400 X 400 KM's with 1,440,000 elevation points.

The 2D graphical display is composed of the terrain map (DTED), terrain overlays (DFAD), R&S plan overlays, and icons representing vehicles and their locations. The 2D terrain map and terrain overlays combined make-up a map similar to a paper map.

The terrain is colored or shaded to distinguish between high and low elevations and terrain overlays depict cities, river, wooded areas, swamps, borders and other items of interest.

There are many different types of paper terrain maps. An elevation terrain map depicts elevations above sea level, and gives some indications of the shape of the terrain and LOS visibility. Slope maps show what terrain is trafficable, while others may depict lines of communication and drainage. In the case of paper maps, many different maps are needed to perform a thorough analysis of the terrain. A computer map only needs one map produced from DTED data and many different overlays (DFAD and R&S). The Automated Reconnaissance and Surveillance Planning Tool uses this technique. It shades the map according to the slope of the terrain or the elevation. The shading is color-mapped or gray scaled to depict elevations, or color-mapped to depict slopes. Then overlays depicting soil composition, tree density, cities, and other potential obstacles can be placed on one or both of these maps. The result is a computer generated Modified Combined Obstacle Overlay (MCOO). [FM 34-130]

The MCOO is a graphical terrain analysis on which all other IPB products are based. It is the basic product of the battlefield area evaluation, terrain analysis, and weather analysis phases of the IPB process. MCOO's are always prepared at all echelons, and the level of detailed always varies based on the time, assets, and personnel available to produce it [FM 34-130]. The computer generated MCOO created in the thesis can ensure all echelons enjoy the best information available.

2. Elevation Maps

A color-mapped elevation map assigns a color for every elevation point based on the relative height of the point. A normalized scale of heights for the current map is generated from the lowest to the highest elevation Equation 5.2.

$$V_{\text{normelev}} = 90 \times \frac{(\text{ELEV}[\text{LAT}, \text{LONG}] - \text{MINELEV})}{\text{MAXELEV} - \text{MINELEV}} \quad (\text{Eq 5.2})$$

The normalized elevation (NORMELEV) is used as an index into an array of colors (Table 1). Each color array adds a unique and informative perspective to the maps. Larger color arrays should be used if there are significant difference in elevation on a single map.

TABLE 1: ELEVATION COLOR-MAP ARRAY

INDEX	R	G	B
0	0	0	255
.	.	.	.
90	255	255	255

One of 90 colors are assigned to each normalized elevation point. Blue is assigned to locations with relative elevations of zero, greens assigned to lower elevations, and shades of grays, reds, and black are assigned to higher elevations respectively (Figure 6). For most maps, the shading scheme will give indications of drainage and vegetation when the information is not available on overlays. These indication are derived from the expectation that vegetation (GREEN) is more likely in lower grounds than at higher elevations, and the fact that water flows down hill and puddles in areas of constant elevations.

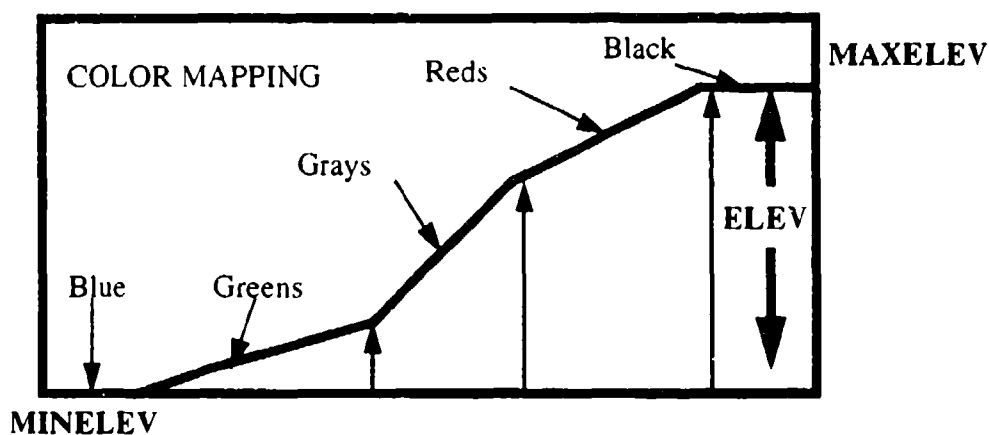


Figure 6: Elevation Map Color Mapping

3. Slope Maps

A color is assigned to every elevation point on the slope map based on the average slope of the terrain in the four cardinal direction immediately surrounding the point (Figure 8). The average slope is then used as an index into an array of 90 different colors Table 1. Since slopes are measured in degrees, there only needs to be 90 different colors to represent each point on the map.

The purpose of a slope map is to determine the whether a point on the terrain is trafficable by wheeled or tracked vehicles based on the slope of the terrain. Maps depicting cross country mobility divide the map into three color ranges (Figure 7). Points with slopes greater than or equal to 30 degrees are considered NO GO and are assigned shades of red. SLOW GO terrain is marginally trafficable terrain that ranges between 10 and 30 degrees of slope. These locations are assigned shades of yellow. Finally, GO terrain is areas where the slope is less than 10 degrees. These areas are shaded gray. NO GO, SLOW GO, and GO terrain on a slope map are based solely on the slope of the terrain. With the assigned color scheme, mobility corridors are represented by the GO and SLOW GO terrain. Map resolution plays a big factor in determining how representative the color scheme is of the actual terrain. The primary consideration is the distance between two adjacent elevation points (Equation 5.3). Shorter distances between adjacent points creates a map which is more indicative of the actual terrain. An excellent automated terrain analysis (MCOO) is created when soil composition, vegetation, water and other obstacles are placed on a slope map. These additions reduce the width and number of mobility corridors providing for a more focused picture.

Previously, paper slope maps were used for this analysis. However, paper slope maps are rare. Hence this technique is usually performed only at higher echelons. But by automating the process through the use of the Automated Reconnaissance and Surveillance Planning Tool, all echelons enjoy the same quality of information.

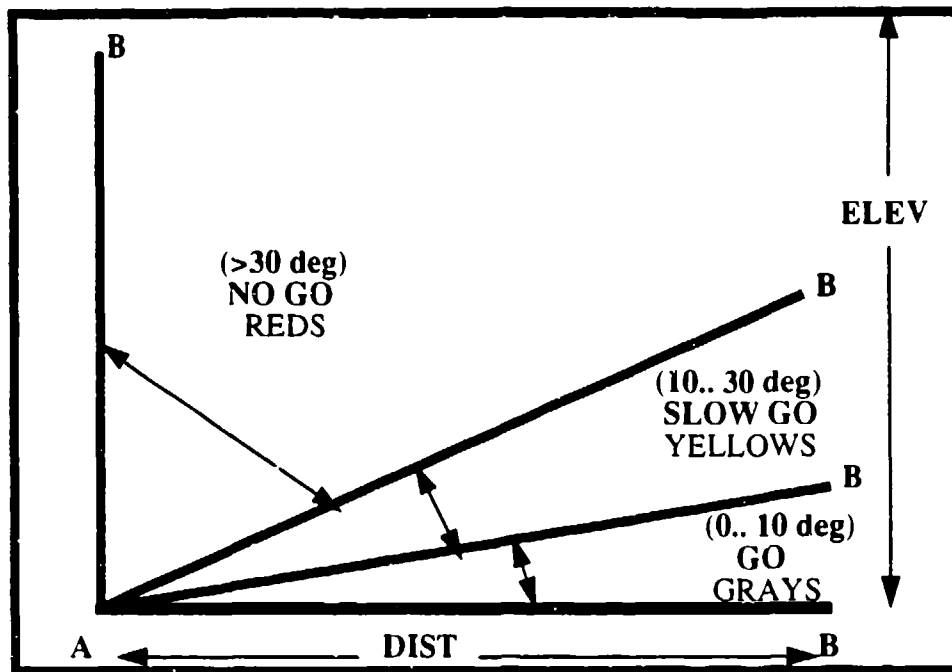


Figure 7: Slope Calculation

$$\text{Slope} = \frac{180 \times (\text{ELEV (A)} - \text{ELEV (B)})}{3.14 \times \text{DIST (A} \rightarrow \text{B)}} \quad (\text{Eq 5.3})$$

C. DIGITAL OVERLAYS

Digital Overlays are lists of information that are displayed on top of DTED data. Information ranges from standard map features to dynamic R&S plans. Digital overlays enable the user to pick which specific information he wants displayed on the map.

Standard overlays such as those that come from DFAD data are essential to a thorough terrain analysis. The advantage of standard overlays is that all echelons enjoy the same quality of information. Also, unlike paper maps, DFAD data allows as many features to be displayed at a time as desired. This prevents a cluttered map. DMA Standard Format DFAD data is stored in two separate binary files [DFAD 86]. The DFAD data is preloaded into the R&S Planning Tool. The data is stored in a complex data structure which allows for unlimited storage of DFAD data in Random Access Memory (RAM) memory and increases the performance of the system by removing the need for file I/O (Figure 9).

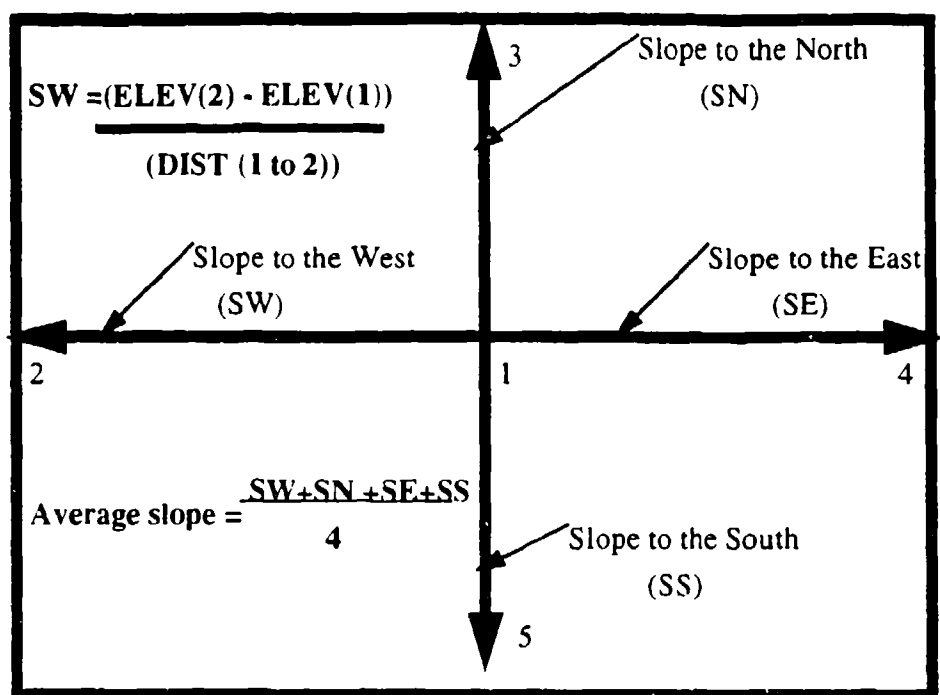


Figure 8: Slope Classification and Color Scales

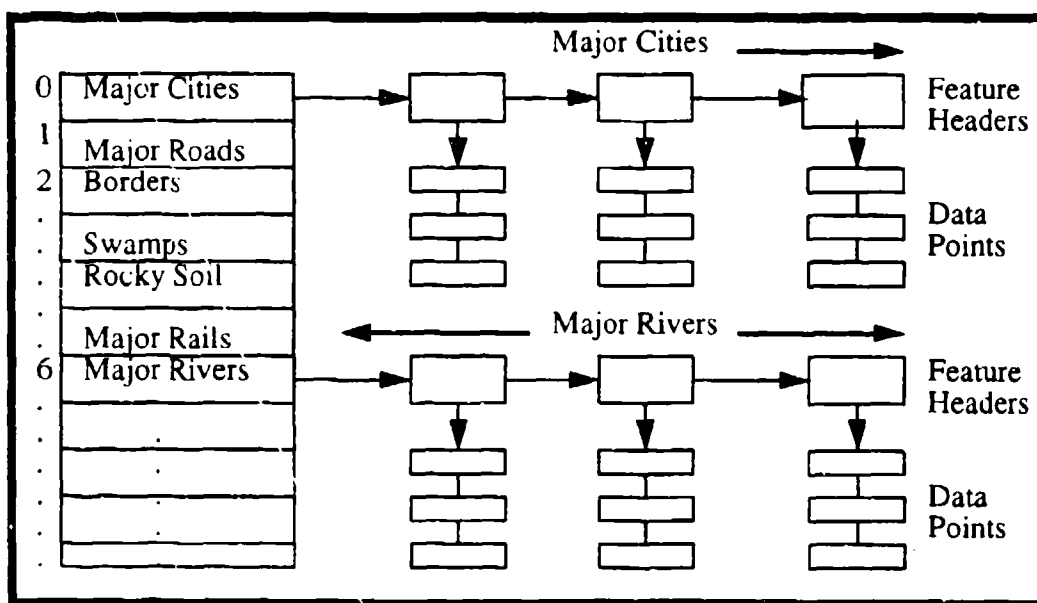


Figure 9: DFAD Data Structure

Non-standard overlays such as R&S Plans, Situation, Event and Decision Support Templates have to be generated through a user interface and stored to disk for future reference. Once created, the non-standard overlays are stored in a data structure similar to that seen in Figure 9. These overlays change over time and are unit specific. Only R&S Plans are generated in the Automated Reconnaissance and Surveillance Tool.

R&S plans are created through a graphical interface on top the computer generated MCOO. Reconnaissance Routes, Named Area of Interest (NAI), Decision Points (DP), Targeted Areas of Interest (TAI), Objectives (OBJ), and Avenues of Approach are depicted in the R&S plan. Once created, Reconnaissance assets are tasked by which reconnaissance route to follow, and which NAI's, TAI's, Avenues of Approach or Objectives to watch. The 2D display is a natural interface for creating and depicting the R&S plan.

D. ICONIC VEHICLES

There are three basic types of iconic vehicles Reconnaissance, Driven, and Semiautomated. Reconnaissance vehicles are defined generated, and managed in the Reconnaissance and Surveillance Planning Tool. This allows the user to develop the R&S plan and manage the reconnaissance assets without influencing the semiautomated or interactively played (Driven) forces. Driven and Semiautomated forces are defined, generated and controlled by either NPSNET or the JANUS Combat Model. These vehicles types and locations are imported via a network message into the R&S Planning Tool when networked to one or both of these systems (Figure 10). The vehicle types are matched with appropriate icons and placed on the 2D representation of the map. The icons are symbolic of the asset they represent, but are not military standard symbols. Future versions will incorporate standard symbols.

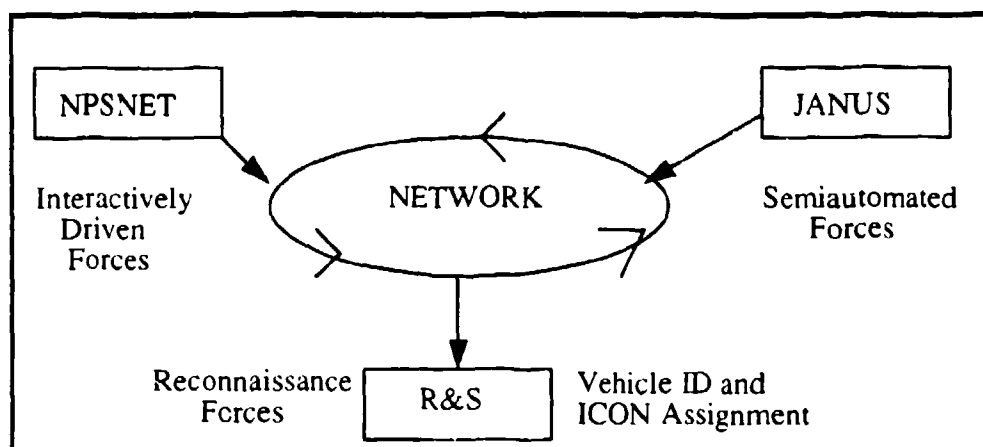


Figure 10: Vehicle Sources and System Control

E. THE 2D DISPLAY

The Silicon Graphics Inc. (SGI) VGX family of computers provides special hardware that speeds up the display of the iconic symbols. The SGI computers provide for overlay planes that are used to store information changes rapidly such as the position of icon images. The overlay planes are bitmapped on to the front buffer plane. Maps and graphical overlays that require significant time to render are drawn and stored in the buffer planes, and icons are drawn in the overlay planes. This allows icons to move across the screen without destroying the visual integrity of the map and map overlays. By using the overlay planes, time is not spent drawing the map every time a vehicle moves.

Since maps and map overlays share the same display plane, maps are always drawn first. Overlays are then drawn on top of the map preserving the integrity of the display. If overlays are removed from the display, then the map and the remaining overlays have to be redrawn. Drawing large maps is the most time consuming process; Therefore, it needs to be done only when necessary.

The 2D display of the map, overlays, and iconic vehicle provide a quick visual understanding of the terrain as well as the known locations and type of vehicles with the bounds of the map. The 2D display is the primary source of information concerning cross country mobility, vehicle identification and location, and the display of DFAD data in the

R&S Planning Tool. Therefore, the 2D display is flexible. As little or as much information can be displayed as desired. Switching between map types, map overlays, and map features creates the clear picture without accidentally misaligning overlays. The 2D display is efficient, accurate, and informative.

VI. 3D GRAPHICS AND MAPS

A. INTRODUCTION

The SGI family of computers are equipped with special hardware and software that enables the display and traversing of 3D virtual worlds. By providing actual terrain data, 3D virtual world models can be built and traversed. This capability provides a new and unique way to gather LOS information that a 2D map can not provide. Unfortunately virtual world models of terrain data alone do not imitate the effects of vegetation. However, 3D terrain models of actual locations are useful in areas where visiting the actual terrain is not an option.

The 3D terrain in this thesis provides for a relatively new perspective of maps and the battlefield. The best maps for planning and rehearsing for military operations are 3D terrain models of the battlefield built out of sand, clay, or plaster. These models take hours to build and are only used for planning and rehearsals. To travel through the actual terrain, if possible could require hours or days, but a computer generated 3D terrain model only takes minutes to traverse. One major advantage of 3D map rendering is one can see the lay of the land from any elevation above the map and from any location. For the same reconnaissance on the actual terrain, the resources required would be astronomical. 3D terrain rendering on SGI computers is fast, efficient, and informative.

3D terrain rendering serves two purposes in this thesis. First it serves as 3D terrain model for visualizing the terrain being studied. Second, the perspective used to view the 3D terrain model emulates the view through a video camera. Since many reconnaissance platforms use video as their primary method of collecting, this perspective is useful in modeling these assets' real-time collection effort.

B. 3D MAP RENDERING

Items that are displayed in 3D must be broken into planar components. The components are reconnected to form the total object. Since it takes three points to define

a plane, the most efficient planar object to render is a triangular polygon. A DTED terrain map can be rendered using this method. Figure 11.

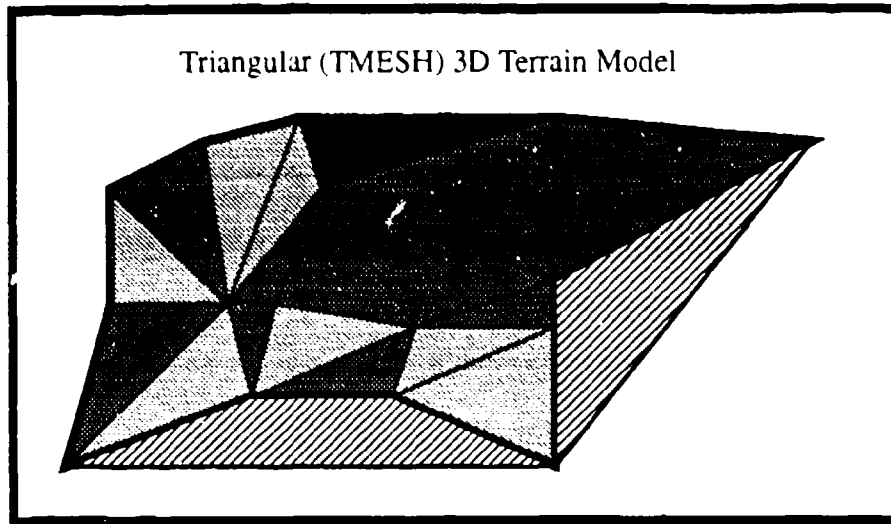


Figure 11: Planer Components of a Terrain Model

3D terrain models are built using a DMA's DTED data and the graphics library functions bgntmesh and endtmesh. The tmesh algorithm uses triangles and therefore is the most is efficient methods for rendering the 3D terrain. When using 3D rendering, the X and Z axis define the horizontal planes and the Y axis defines the vertical, Figure 12.

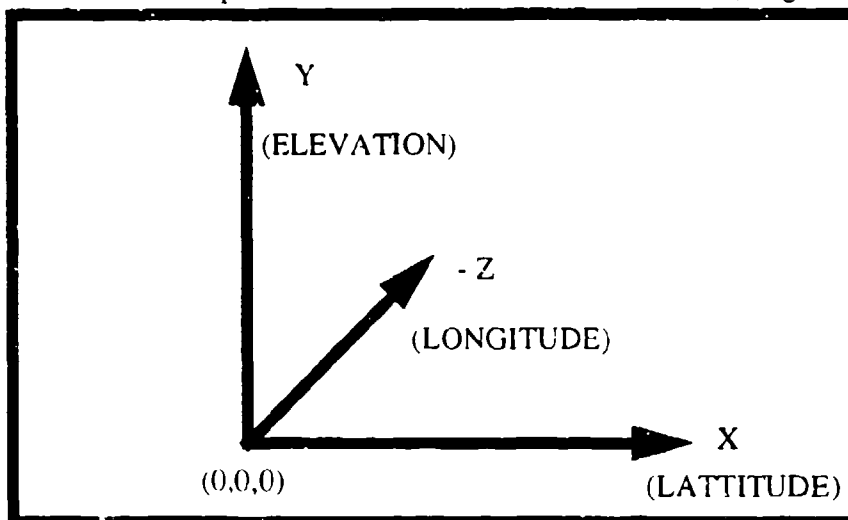


Figure 12: 3D COORDINATE SYSTEM

When terrain is rendered in 3D, lines of latitude (LAT) are represented by the X axis, and lines of longitude (LONG) are represented by the Z axis. The Y axis represents the elevation (ELEV) at a particular location (LAT, LONG). The elevation of the lower left hand corner of the map is placed at coordinates (0,0,ELEV). Maps are drawn in the tmesh mode by starting at the lower left hand corner Figure 13. Figure 13 depicts the tmesh rendering by starting at coordinate (0,1), drawing to (0,0), then to (1,0) and ending by closing the triangle assigning it a color. Triangle 1 is completed. Then by adding only one vertex (1,1) triangle 2 is completed and so on. Each vertex of the triangles is assigned an elevation creating a 3D map. A tmesh algorithm cycles systematically adding a new elevation point and creating a new adjoining triangle with each vertex.

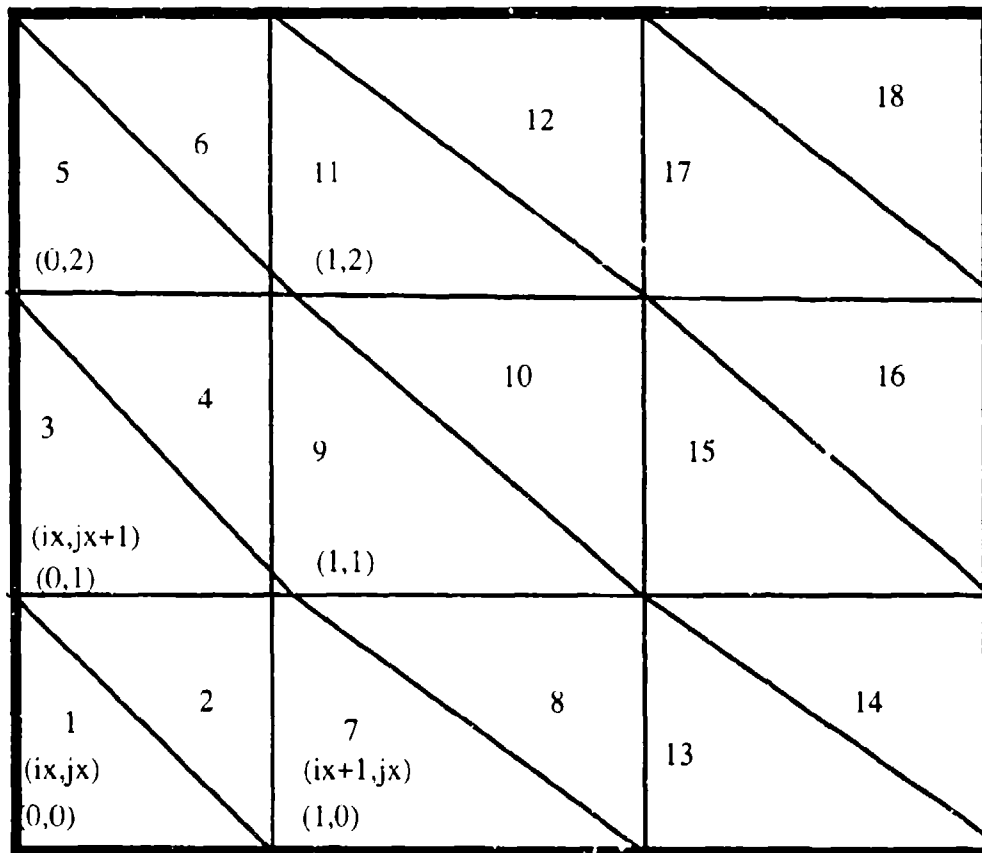


Figure 13: TMESH Triangles

C. 3D MAP SHADING

This thesis uses two methods for coloring the virtual world terrain. The first method used to shade the terrain creates an elevation map. When the virtual world is shaded by the elevation color map, all locations that are at the same elevation are colored the same and therefore are spotted at a glance Figure 14. The second method creates a slope map. The

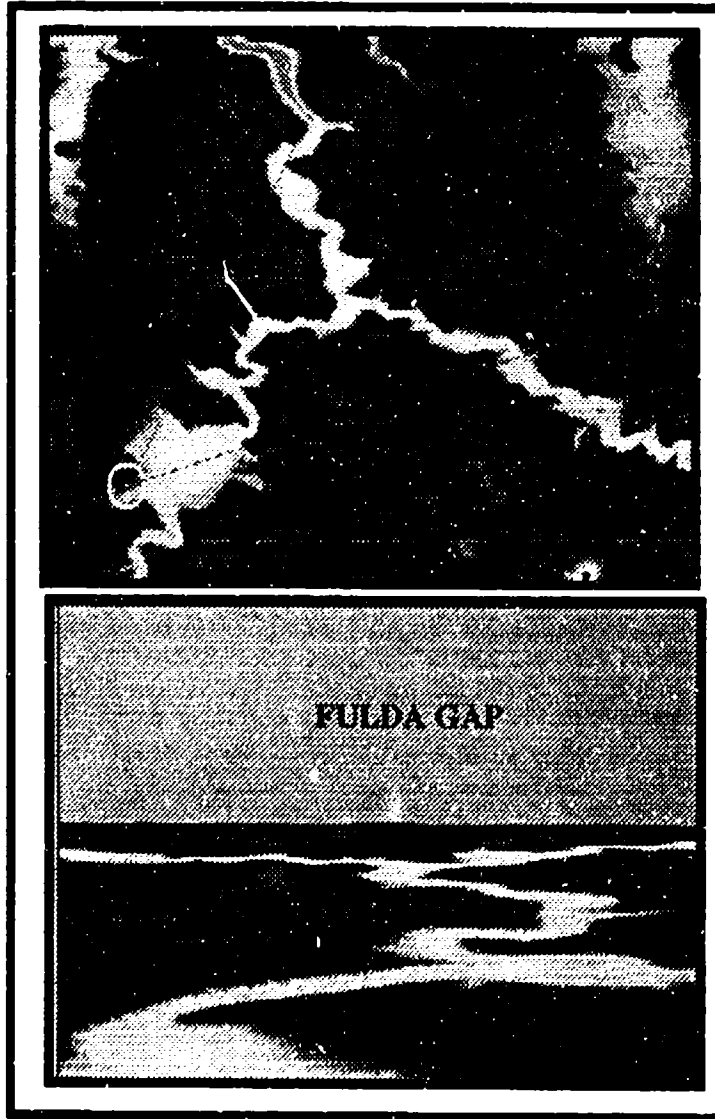


Figure 14: 2D and 3D View with Elevation Color-Mapping

shading scheme is the same as that used in the 2D map rendering, but the appearance is different. When traveling through the 3D world, one sees the terrain that is too steep to

travel at a glance, Figure 15. Both of these methods provide unique and useful information about the terrain.

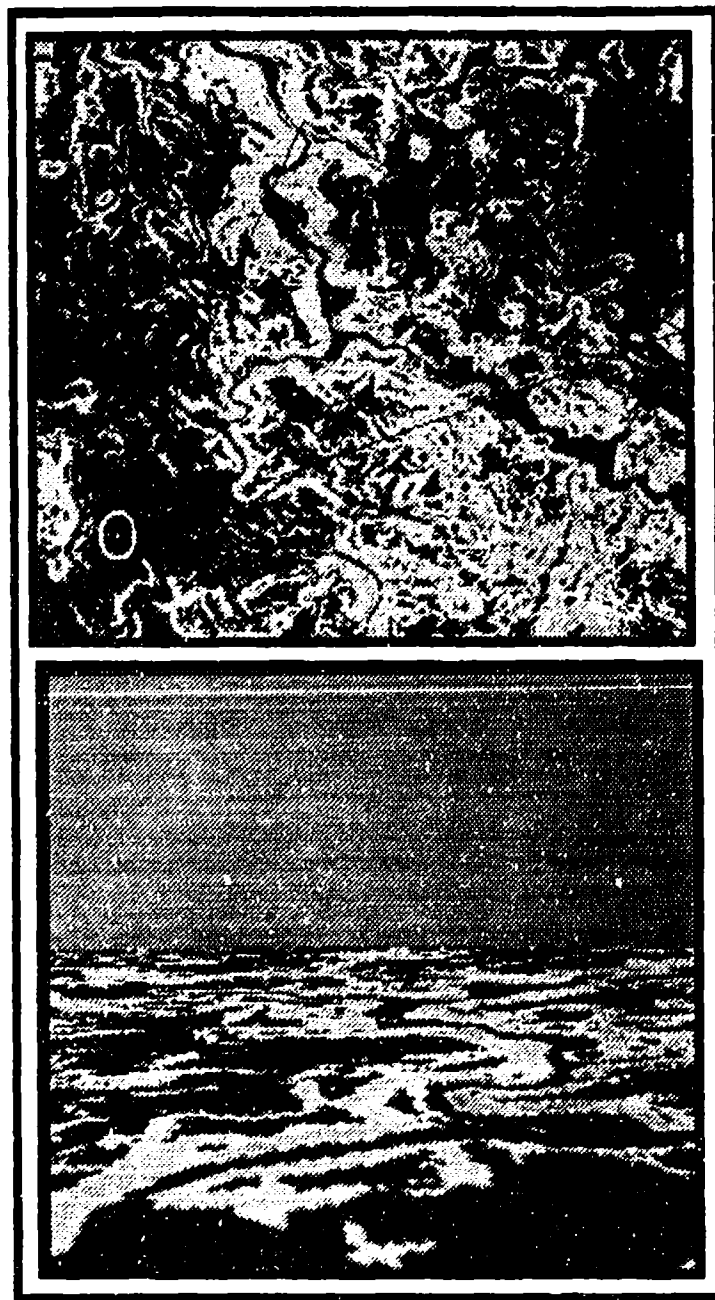


Figure 15: 2D and 3D View with Slope Color-Mapping

D. 3D OVERLAYS

While this thesis does not incorporate 3D overlays, it is important to know that this is already incorporated in NPSNET and could be included in future versions of this program for visual affects [ZYDA 92]. 3D overlays are the projections of DFAD data and iconic vehicles onto the 3D map. 3D models for these images must be created and placed at the appropriate location on the map. They are divided into moving and stationary models. Moving models must both appear and dynamically move similar to the real world systems. Models like generic trees and buildings, T-72 tanks, and others whose appearance is known are modeled ahead of time and placed in memory for to be drawn at the appropriate locations. Roads, swamps, and forest whose shape and appearances are not known must be modeled though the use of DFAD data and textures. 3D overlays add a level of visual reality to virtual worlds making them a desirable addition.

VII. MAKING THE SYSTEM SMART

A. AI APPLICATIONS

Artificial Intelligence (AI) plays a big part in the Automated Reconnaissance and Surveillance Planning Tool. It is used to determine information about the terrain and enemy that would otherwise be unknown. There are two AI applications used in this thesis. Each application has its own set of rules that were developed by experts in the Army Intelligence community. The first application uses a process that identifies mobility corridors. Mobility corridors are generated through a process that diverts the operators attention from non-trafficable terrain by shading it differently from trafficable terrain. The second AI application attempts to analyze information collected about the enemy forces and determines the enemy's current situation and probable courses of action. This application is a separate program designed to work with the Automated R&S Planning Tool.

B. MOBILITY CORRIDOR IDENTIFICATION

Mobility corridors are areas which permit movement and maneuver. These are generated by marking areas where wheeled and tracked vehicles can not travel colors other than gray. The process starts by coloring the terrain shades of red where the slope is greater than 30 degrees. Then elements of the DFAD data that inhibit cross country mobility are overlaid and marked with their appropriate color. The remaining areas that are shaded gray clearly mark the mobility corridors. The following rules are used to determine whether the terrain is trafficable.

- Slope of Terrain ((0->10) GO, (11->30) SLOW GO, (>30) NO GO)
- Vegetation (Density and Tree Trunk Diameter)
- Walls and Fences (Material and Thickness)
- Soils (Swamps, Marshes, and Rocky Soils)
- Deep Water (Rivers, Lakes, Oceans, and Fast Currents)
- Dense Urban Areas (Narrow Streets) [FM 34-130]

Areas that are not adversely affected by the slopes, vegetation, walls, soils, water, or urban developments are mobility corridors.

This expert system identifies the mobility corridors based on the capabilities and equipment of Soviet mechanized forces in the same manner as Army Intelligence Officers are trained to perform. The mobility corridors are not applicable to soldiers who walk or fly to the battlefield. Soviet mechanized forces, tanks and other ground vehicles, are incapable of traversing terrain with slopes greater than 30 degrees and generally prefer to travel high speed avenues of approach [FM 100-2-3]. As the rules indicate, any obstacles, man-made or natural, which impede, stop or divert maneuver are usually avoided [FM 100-2-1]. Those areas which can not be avoided but do contain obstacles require preparation in order for it to support maneuver. This expert system identifies all NO GO, SLOW GO, and GO terrain consistently and quickly.

C. ENEMY SITUATION ANALYSIS PROGRAM

The hardest thing an Army intelligence officer does is build an affective R&S Plan. The second hardest is the assembly and analysis of the data retrieved through the execution of that plan. The Enemy Situation and Analysis System makes that process faster and more simple.

This expert system is written in Common LISP and is designed to work in conjunction with the Automated R&S Planning Tool. The expert system reads files generated by the Automated R&S Planning Tool concerning the locations time and types of vehicles reported by the intelligence collection assets. This information is then processed through a set of rules in order to determine whether the enemy will attack or defend as well as determine enemy trends and dispositions. The rules used in this expert system are a subset of a list of indicators developed by a by the Army Intelligence Center, Fort Huachuca, AZ. [TACT 85]. The following rules are used to indicate the enemy will attack.

- The opposing force is a regiment or larger.
- Tanks forward of Mechanized Forces (Infantry)
- Little engineer preparation

- Engineers forward but not digging
- Location of Reserve Forces.

The following rules indicate the enemy will defend.

- Opposing Force is <50% strength of Regiment.
- Extensive Engineer preparation
- Tanks behind mechanized forces
- Tanks in reserve.
- Strong Electronic Air Defense Signature

Each of these indicators are assigned a likelihood value. After analysis, the likelihood values for each course of action are summed creating a likelihood value for each course of action. The values for each course of action are compared and the one with the highest number is assigned the most probable course of action. The operator of the Enemy Situation and Analysis Program has the ability through an interactive menu to view the raw and processed data used to develop the most probable courses of action. This ensures the human remains in the loop.

This program is designed to perform the mundane bean counting of enemy vehicles reported as a result of the execution of that R&S plan. The R&S Planning Tool generates a file that contains all collected reconnaissance reports and formats them to take the form of Common Lisp variables. The file format is the same as that seen in Appendix C. The sample file in Appendix C works in 30 minute increments, where the R&S Planning Tool's time increments are random.

This expert system will tell what echelon force you are facing up to a Motorized Rifle Regiment (MRR). If the enemy unit is larger than a MRR, it will tell you, "You are facing at least a division (type Unknown)". The logic used to determine the size of the force has three input parameters: Time, Number and types of vehicles, and Location. The size of the force is determined by the number of tanks and armored personnel carriers reported at a

particular location and time. The number of tanks and APC's found in each echelon from platoon to Regiment is found in Table 2.

TABLE 2: NUMBER OF TANKS AND APC's PER ECHELON

ECHELON	TANKS	APC's
Motorized Rifle Platoon	0	3
Tank Platoon	4	0
Motorized Rifle Company	0	13
Tank Company	12	0
Motorized Rifle Battalion	4	43
Motorized Rifle Regiment or Larger	12	>43

The final output of the expert system is the prediction of the most probable enemy course of action. Probable courses of action are determined based on three basic facts. First it calculates the percent strength based on the numbers and types of combat vehicles in an MRR. According to written Soviet doctrine, units smaller than MRR's will not perform individual offensive operations[FM 100-2-1]. The number of hours spent preparing defensive positions by engineer assets is the second indicator. Lastly, the location of reserves or reinforcements are evaluated. These three indicators form the bases for determining whether the enemy will attack or defend.

D. SUMMARY

Intelligence is created by processing combat information and raw collected data. Since intelligence on the terrain and enemy comes with out guarantees, AI is used to maximize the probability of getting the right answers. Processing raw data into intelligence is an art. The techniques used can not be modeled directly by an algorithm do to the built in

uncertainties. Therefore an expert system that is good will help the intelligence community create good intelligence.

VIII. CONCLUSIONS

A. OBJECTIVE

The objective of this thesis was to create an Automated Reconnaissance and Surveillance and Planning Tool that can be used as an intelligence interface to NPSNET as well as serve as a prototype for the Army's proposed CGS. In order to achieve this goal, several subordinate tasks had to be accomplished. Map media had to be collected and displayed, intelligence systems had to be modeled, an R&S plan generator had to be created, an expert system had to be built, and then the tool had to be networked with NPSNET. The tasks are summarized in the following section. Accomplishments are noted and, unsolved issues are identified. Recommendations for future research are discussed in the last section.

1. Maps

The first objective was to build a system that could use DMA's DTED and DFAD data to produce maps that are compatible with both NPSNET and CGS. DMA's digital maps were used because they cover larger areas and more areas of the world than those used currently in NPSNET. Since the R&S Planning Tool is also designed to work with CGS and the Army's mission is world wide, DMA maps were a necessity.

DTED and DFAD data were obtained through the Army Intelligence Center's Artificial Intelligence Laboratory, Ft. Huachuca, Arizona. Maps of Europe, Korea, and the Army's National Training Center (NTC) were used in this research. A map that contained the Fulda Gap in Germany was used as the common map for interfacing with NPSNET and JANUS. Other maps were used to help create informative slope and elevation map displays that depict mobility corridors and attempt to predict the appearance of the terrain.

The format for DTED data was clear, but DFAD data rendering is not perfected. Linear features are depicted correctly. Area features appear in the correct place but are

distorted. There was not enough information available to correct this problem in a timely manner.

2. System Modeling

Modeling intelligence systems capabilities is a touchy subject that requires a clear delineation as to what capabilities are classified. The characteristics modeled in this research are not classified. Hence, they may not reflect the true capability of the collection systems. The system modeling is symbolic of the actual systems and therefore creates a realistic intelligence interface for NPSNET and JANUS.

There were two basic type of intelligence systems modeled. The first type uses video imagery or other visual aids to identify and locate the threat forces. The views are replicated through 3D virtual world perspectives of the terrain. The second type modeled uses active electromagnetic radiation (RADARS) to locate and identify moving targets with in their range. The systems were modeled by placing icons representing vehicles on a 2D map covering only the areas they are watching. These icons represent Moving Target Indicators (MTI). MTI's appear only if a vehicle is in radar line of sight of the system and it is moving. A key aspect that is desired in CGS is the ability to simultaneously monitor the real-time collection efforts of multiple systems from a single monitor. This was accomplished in this thesis.

System modeling is incomplete. While the perspective of these systems are complete, collision detection still needs to be implemented to determine whether or not a particular intelligence collection system detected a threat vehicle. This part is necessary in order to generate the file needed by the Enemy Situation and Analysis Expert System. Additionally there is no system that attaches the intelligence collection plan to the intelligence collection assets.

3. Plan Building Interface

The R&S plan building interface is complete. This interfaces could be expanded to make it more robust. The data structures provide for complex graphical plans. The

current pick mechanisms used to select buttons tracks the location of the mouse cursor to ensure it is within the bounds of the buttons. This section of code could cause problems in future editions.

4. Network to NPSNET and JANUS

Networking the Automated R&S Planning Tool to JANUS and NPSNET was difficult. Map compatibility was the big obstacle. The Fulda Gap, Germany provided the only common ground between NPSNET, JANUS, and the Automated R&S Planning Tool. NPSNET and JANUS maps are not built from standard DMA data. The maps only a cover 13 X 13 KM piece of land, while the standard DTED data covers up to 400 X 400 KM pieces of land. This meant that JANUS and NPSNET would run in only 4% of the R&S map. The R&S Planning Tool needs higher resolution maps for zooming in on smaller areas of land.

A second problem encountered was the message contents passed. The R&S Planning Tool needs map and world information passed at least once across the net. The data for the Fulda version is hard coded into the R&S Planning Tool. If map and world coordinates were passed, the hard coding could be replaced so that other maps could be used in the future. This will make for a more robust CGS trainer in the future.

5. Build Expert System

The expert system that automatically generates the mobility corridors is complete. Four maps with significantly different terrain were tested with favorable results.

Likewise, the Enemy Situation and Analysis expert system is also complete. Three different sample data files were generated and tested on the Enemy Situation and Analysis expert system. The system provided adequate intelligence on the sample scenarios. The real test will be against NPSNET and JANUS produced scenarios. This test can not be performed currently. The LOS algorithms used to determine which vehicles are detected by the intelligence collection assets have not been incorporated do to time

constraints. Future work in this area has the potential for big breakthroughs in the intelligence processing field.

B. RECOMENDATIONS AND FUTURE RESEARCH

Reconnaissance and surveillance planning and intelligence collection, analysis, dissemination will be automated in the future. The automation of this process will enhance the Army's ability to fight and win on the modern battlefield. I feel continued work in developing this system will result in a better battlefield simulator and potential trainer for the Common Ground Station.

Research areas that would help the advancement of Automated intelligence would include:

1. Intelligence Plan Building and Testing Against NPSNET and JANUS

This subject would incorporate connecting the R&S plan generator to the R&S assets. Additionally it would mean developing the enemy detection algorithms unique to these collection assets. Finally it would mean Connecting the R&S Planning Tool to the Enemy Situation and Analysis Expert System via a file similar to that in Appendix C.

The testing could incorporate letting two different intelligence officers generate and execute an intelligence collection plan against an NPSNET or JANUS generated scenario. At a minimum, the expert system could generate the percent of the opposing force that was detected by each intelligence plan. This alone could help in training future intelligence personnel.

2. Develop A CGS

In concept, CGS is a computer that take raw or precessed data through communication ports and presents the data in an intelligent format. The inputs would take the form of real-time video links, digital report formats on moving targets, still imagery, digitized formatted intelligence reports. This information would have to be digested and presented concurrently. The point of contact concerning this system is: TRADOC

SYSTEM MANAGER for Common Ground Station, Army Intelligence Center, FT, Huachuca, Az 85615.

C. CONCLUSION

The Automated Reconnaissance and Planning Tool is a good start for future research in automating intelligence collection, analysis, and dissemination. Developments like CGS and ASAS require continuous improvement in order to keep up with technology and to keep the United States stronger than its enemies. Developments like the Automated Reconnaissance and Surveillance Planning Tool may provide unique and informative to the systems of the future.

APPENDIX A. USERS GUIDE

A. PROGRAM DESCRIPTION

The Automated Reconnaissance and Surveillance and Planning Tool program is subdivided into four major blocks. The first block is the start up block (Figure 16). The start-up block consists of the initialization of the SGI hardware and if the networking mode is desired, it the initialization of the network happens in this block. The second block only consist of the initialization of data (Figure 16). It is referred to as the preprocessing block. In this phase, appropriate maps and overlays are loaded, reconnaissance vehicles are initialized, average slopes and relative elevations are calculated, and colors are assigned for the elevation and slope maps. The third block is the display loop (Figure 16). In the display loop the following processes are accomplished:

- Input from the network is received. (If in the networking mode.)
- The menu and keyboard are checked for input.
- The 2D Map is drawn.
- The 2D Overlays are drawn.
- Icons are drawn at the appropriate locations.
- The 3D Terrain is drawn.
- Each of the Recon Assets views are drawn.

The display loop exited under three conditions. Each of these conditions are initiated from a menu selection. The first condition is to terminate the program (See "Exit" on page 58). The second condition is Change maps. If the map is changed all data is reinitialized (See "Change Maps" on page 52). The third condition leaves the display loop to enter the Create R&S Plan Loop. The R&S Plan Loop will continue until it is terminated. When the R&S Plan Loop is terminated, it returns control to the display loop. The last block is the R&S Plan Loop (Figure 16). The R&S Plan Loop is entered when the Create R&S Plan option is selected from the main menu. The R&S Plan loop is similar to the Display Loop. The 3D or Reconnaissance Views are eliminated from the R&S Plan Loop, and a window

containing buttons for input is added (See "R&S PLAN BUILDING MODE" on page 58).

The flow of the program is portrayed in Figure 16.

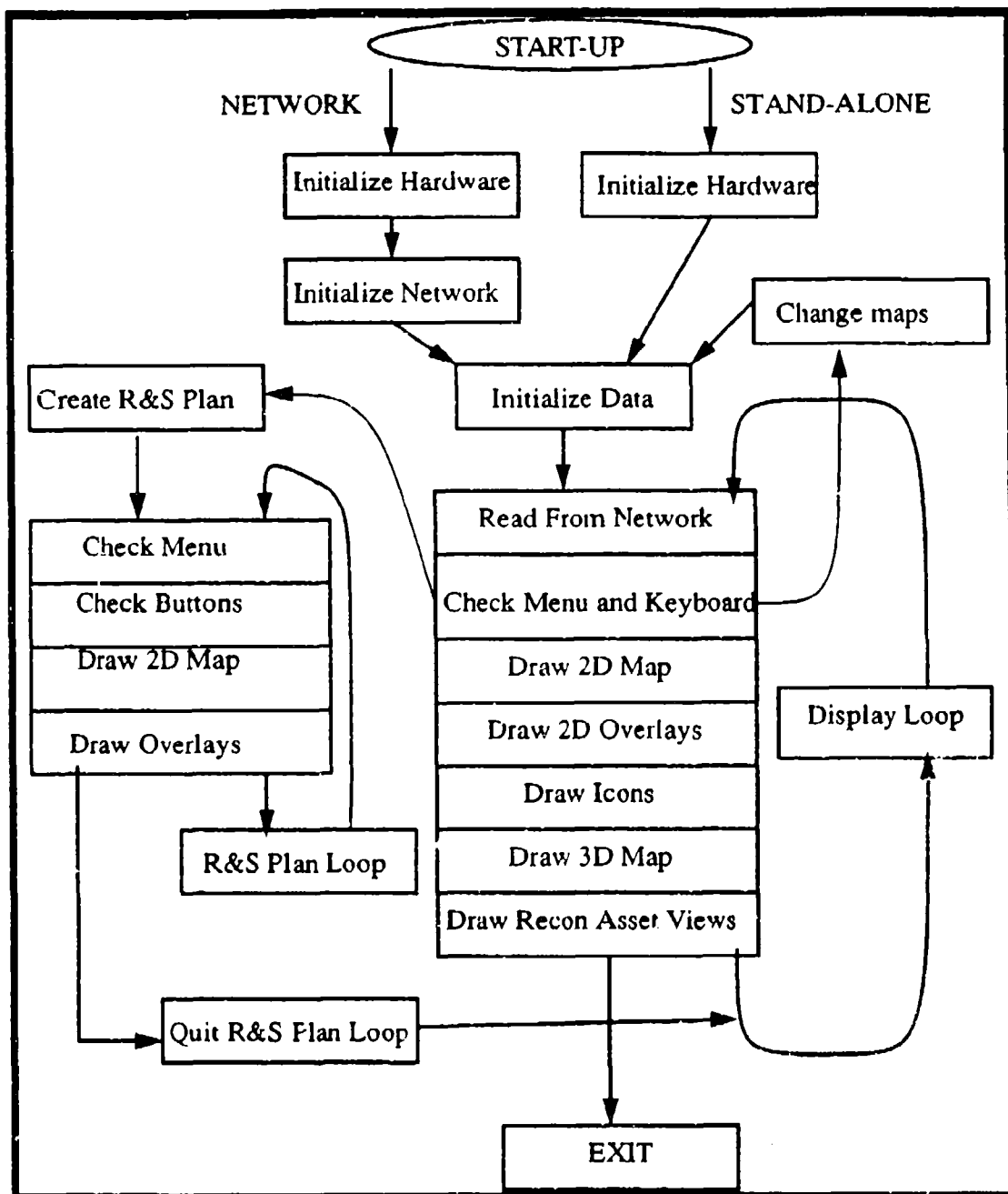


Figure 16: PROGRAM FLOW DIAGRAM

B. HARDWARE

The Automated Reconnaissance and Surveillance Planning Tool is designed to run on the Silicon Graphics Inc. family of computers. It uses DMA Standard Format DTED and DFAD mapping data.

C. SOURCE CODE FILES

The source code for this application is contained in the following files and categories:

TABLE 3: R&S PLANNING TOOL FILES

HEADER FILES:	ntc2d.h	cmap.h fontdef.h	externs.h network.h	features.h recon_plan.h
MAIN ROUTINE:	newmap.c			
SUBPROGRAMS:	motion.c menus.c maps.c	draw_overlays.c infoscreen.c	recon_plan.c draw_feature.c	fontdef.c network.c
DATA FILES:	<u>North Korea</u>	<u>Germany</u>	<u>Czechoslovakia</u>	<u>NTC</u>
TEXT (LAT/LON)	chosin-korea	fulda	chech	ntc
DTED	42N.130E.ele	51N.9E.ele	50N.15E.ele	35N.117W.ele
DFAD Headers	42N.130E.hdr	51N.9E.hdr	50N.15E.hdr	
DFAD Data	42N.130E.dat	51N.9E.dat	50N.15E.dat	

Appropriate SGI library files are included by the header files listed above. The files listed above are found in /n/gravy1/work/bill/thesis/ntc. The file "Makefile" contains the command necessary to compile the code to an executable file. If this tool is to be run with NPSNET or JANUS, these programs may need to be compiled and started. See "STARTING THE PROGRAM" on page 51.

D. COMPILATION

The Automated R&S Planning Tool is compiled by the following method:

- Change directories to ~bill/thesis/ntc
- Type <make newpre2d>

A file newpre2d will be generated and placed in the same directory.

E. STARTING THE PROGRAM

Two methods are used to start the program. The first method is used when the R&S Planning Tool is used as a stand alone system. When this method is used, The following must be typed: newpre2d <TEXT (LAT/LON)> file desired (TABLE 3:). A typical start look as follows: "newpre2d fulda". Depending on the map, the program takes 15 seconds to 3 minutes to start-up. The second method used to start-up the R&S Planning Tool is used when a network is established with NPSNET, JANUS or both. To perform this start-up, first start-up NPSNET (FULDA) or JANUS refer to [WALT 92]. Then on another SGI computer start-up the R&S Planning Tool by typing the following: newpre2d <TEXT (LAT/LON)> file desired (TABLE 3:) N. The 'N' means start-up is in the networking mode. A typical start-up in the network mode looks as follows: "newpre2d fulda n". A second step is also required. Once the program starts, maneuver the mouse cursor inside the 2D map window. Then push the right mouse button and hold. A pop-up menu will appear Figure . Then maneuver the mouse cursor over the "Network System" selection in running properly, semiautomated and Interactively played forces will begin to be displayed on the 2D map.

Drawing Type	
Change Maps	->
2D Map	->
Create R&S Plan	
R&S Overlays	->
Asset Views	->
Map Overlays	->
Change Locations	
Change Vehicles	
3D Map	->
Network System	
Exit	

Figure 17: Network System on Main Menu

F. EXITING THE PROGRAM

To exit the Automated R&S Planning Tool, Select "Exit" on the main menu (Figure).

G. WORKING THE POP-UP MENU

The pup-up menu is activated by pushing the right mouse button and holding it down. Then maneuver the mouse cursor over the menu selection and release. All items on the main menu with out the "->" provide a specific function requiring additional instructions. These selection will be described individually later. The selections with the "->" have slide-off (SUB-MENUS). To activate a SUB-MENU, first activate the main menu as described above and maneuver the mouse cursor over a selection with a "->" and slide the mouse over the "->" and a Sub-Menu will appear. Sub-Menus selections are made in the same manner as main menu selection.

H. MENU SELECTION DESCRIPTIONS

1. Change Maps

The **Change Maps** selection activates a Sub-Menu. Once the Sub-Menu is activated a selection is made Figure 18. **Change maps** allows the user to switch to one of the maps listed in the Sub-Menu. A message will be displayed informing the user that the computer is processing. During this time, no operations can be made. When the new map is displayed normal operations will continue.

Select Map
North Korea
NTC
Czechoslovakia
Fulda

Figure 18: Select Map Sub-Menu

2. 2D Map

The **2D Map** selection activates a Sub-Menu. Once the Sub-Menu is activated a selection is made Figure 19. 2D Map allows the user to display the 2D map in a desired

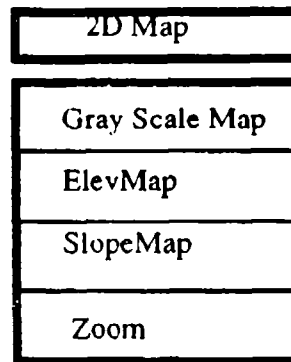


Figure 19: 2D Map Sub-Menu

form. **Gray Scale Map** displays the 2D map in a black and white image. The highest elevation is white and the lowest elevation is black. Elevations between the highest and lowest are shades of gray between white and black. **Elevmap** displays the 2D map according to a predefined color-map. The Elevation Map option is a colored map that makes different elevations stand out from one another. The color scale is designed to predict information about the vegetation when it is not available (See "Elevation Maps" on page 24). The **SlopeMap** selection displays the 2D Map so that it subdivide the terrain into NO GO, SLOW GO, and GO terrain (See "Slope Maps" on page 26). This selection make Mobility Corridors appear. The **Zoom** allows smaller areas of the map to be displayed across the whole screen. To zoom into an area of the map, first select the **Zoom** option. Then move the mouse cursor over the upper left hand corner of the area of the map you want to zoom into. Press the left mouse button and hold it. Drag the mouse button down and right across the map to the lower left hand corner of the portion of the map you want to zoom in on. A white rectangle should outline the area you want to zoom in on. Then release the left mouse button and the zoom will happen. To **Unzoom** press the middle mouse button.

3. Create R&S Plan

The **Create R&S plan** selection puts the R&S planning Tool in the R&S Plan Building Mode. The R&S Plan Building Mode is used to build R&S plans. In this mode a window is opened on the right side of the screen containing buttons. These buttons are used to build a R&S Plan by using the mouse and mouse buttons to draw each aspect of the R&S Plan.

4. R&S Overlays

The **R&S Overlay** selection activates a Sub-Menu. Once the Sub-Menu is activated a selection is made Figure 20. Each of these selections toggle the respective selection On and Off. If no R&S Plan has been built there will be no overlays to display. Overlays are built or loaded in the Create R&S Plan Mode

R&S OVERLAYS
All Overlays
Avenues of Approach
TAI's
NAI's
Decision Points
Recon Routes
Objectives

Figure 20: R&S Overlay Sub-Menu

5. Asset View

The **Asset View** selection activates a Sub-Menu. Once the Sub-Menu is activated a selection is made, Figure 21.

ASSET VIEW	
JSTARS	
RPV VIEW	->
GSR VIEW	->
Mounted Scout's View	->
OP's VIEW	->

Figure 21: Asset View Sub- Menu

The **JSTARS** selection opens a copy of the larger 2D in the upper right hand corner of the screen. Icons representing the Moving vehicle detected by the JSTARS are displayed on the JSTARS 2D Map. The **other** selections have Sub-Menus. The Sub-menus are to so that multiples of these assets can be used. Each of the selections on the sub-menus are open up windows that display what the individual assets see from their perspectives. These selections act as toggles for opening and closing the individual assets view.

6. Map Overlays

The **Map Overlays** selection activates a Sub-Menu. Once the Sub-Menu is activated a selection is made, Figure 22. The selections in the Map Overlays Sub-Menu behave the same as those described in the main menu. The Map Overlays sub-menus is allow DFAD data to be toggled On and Off (See "DIGITAL OVERLAYS" on page 27).

This robust feature allows custom overlays to be built by displaying only what is desired on the map. This feature helps prevent a cluttered map.

Map Overlays	
All Overlays	
Roads	->
Rivers	->
Urban Areas	->
Rails	->
Borders	
Vegetation	
Rocky Soil	
Soft Soil	
Marshes and Boggs	
Walls and Fences	
Pipe Lines	
Grid Lines	

Figure 22: Map Overlays Sub-Menu

7. Change Locations

The **Change Locations** option applies only to the vehicle currently being controlled. The vehicle being controlled can be identified by the white triangle extending from the icon. To change the location of the current vehicle, first select **Change Locations** from the main Menu. Then align the mouse cursor over the position on the 2D Map where you want the current vehicle to be placed. Press the left mouse button again and the vehicle will move to that location.

8. Change Vehicles

The **Change Vehicles** option allows the user to switch to a different reconnaissance asset that is at another location. The new vehicle will become the current vehicle. The current can be identified by the white triangle extending from the icon. This is a two step process. First select the **Change Vehicles** option from the main menu. Then align the mouse cursor over the icon of the vehicle you want to switch too. Finally, press the left mouse button. The white triangle will move to the new vehicle indicating the change has been made.

9. 3D Map

The 3D Map option activates a Sub-Menu. Once the Sub-Menu is activated a selection is made, Figure 23. The **SlopeMap** selection displays the 2D Map so that it

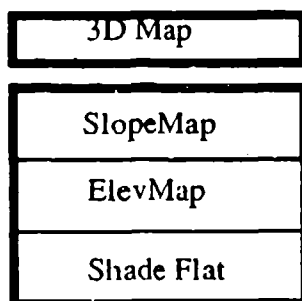


Figure 23: 3D Map Sub-Menu

subdivide the terrain into NO GO, SLOW GO, and GO terrain. See "Slope Maps" on page 26 This selection make Mobility Corridors appear. **ElevMap** displays the 2D map according to a predefined color-map. The Elevation Map option is a colored map that makes different elevations stand out from one another. The color scale is designed to predict information about the vegetation when it is not available (See "Elevation Maps" on page 24). The **Shade Flat** option colors the map so that the individual polygons that make up the terrain show.

10. Network System

This option is only used when the R&S Planning tool is started in the Networking Mode, See "STARTING THE PROGRAM" on page 51.

11. Exit

This option is used to terminate the program.

I. R&S PLAN BUILDING MODE

The R&S plan building mode is an interactive graphics tool that allows the user to build P&S overlays. The program is put into the R&S Plan Building Mode by selecting the **Create R&S Plan** from the Main Menu. A window containing button will appear on the right hand side of the screen. Figure 24

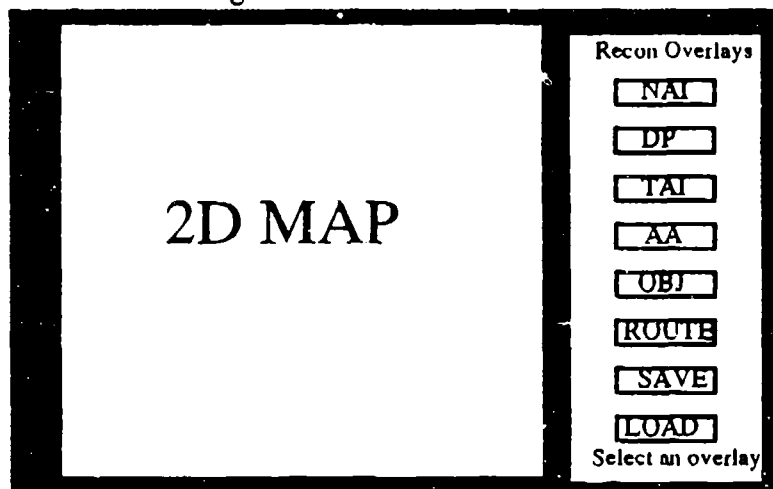


Figure 24: R&S Plan Building Mode Screen

The buttons on the right side of the screen are activated by placing the mouse cursor over the desired button and pressing the left mouse button. The button will turn gray. Only one button can be active at time. Once a button is active, the mouse cursor is place over the map in the desired location on the 2D map to draw the overlay. The Middle button deactivates the button and opens a window so that a name can be assigned to the overlay. Once a name is assigned the next button can be activated. Each button is discussed in detail.

1. NAI Button

The **NAI** button is used to draw Named Areas of Interest (NAI). NAI's are black unfilled multisided polygons that are contoured to a particular area of the map. NAI's represent areas on the terrain that one or more recon assets will be assigned to watch. A NAI is drawn by first pushing the **NAI** button. Then select a point on the 2D Map where the first vertex of the polygon is to be located. Then push the left mouse button and hold it down. Move the mouse cursor to the next location you want a vertex and release the mouse button. A rubber band line will extend from the last point visited and the first vertex creating a polygon. This process can be repeated as many times as desired creating a multisided polygon. When the NAI is complete, press the middle mouse button. A type-in window will appear so a name can be assigned to the NAI. The hit return and start the process over.

2. TAI Button

The **TAI** button is used to draw Targeted Areas of Interest (TAI). TAI's are red unfilled multisided polygons that are usually placed in areas along mobility corridors that constricts traffic. These are the locations in which the enemy will be destroyed. They are drawn the same way NAI's are drawn (See "NAI Button" on page 59).

3. OBJ Button

The **OBJ** button is used to draw friendly objectives. Like the NAI's and TAI's, Objectives must be watched by one or more reconnaissance assets. Objectives are drawn as blue unfilled multisided polygons. Objectives are generally placed on key and decisive terrain (See "K - Key Terrain" on page 2). They are drawn the same way as a NAI's are drawn (See "NAI Button" on page 59).

4. Route Button

The **ROUTE** button is used to draw reconnaissance (recon) routes. Recon routes are made up of black connected line segments from a start point to an end point. These routes start and end at the same place, while others start at one place and end at positions

near Objectives, NAI's, or TAI's. Recon assets are assigned missions that follow these routes. This helps prevent fratricides. Routes in the same manner as NAI's. The major difference is routes are not polygons, therefore the rubber band line will only extend to the last point visited. The middle mouse terminates the route and a name is assigned (See "NAI Button" on page 59).

5. AA Button

The AA button is use to draw Avenues of Approach (AA). Avenues of Approach are red, wide, routes used by the enemy that follow mobility corridors from a start point to an end point. For more information on the function of Avenues of Approach See "A - Avenues of Approach and Mobility Corridors" on page 2 Avenues of Approach are drawn the same way as routes (See "Route Button" on page 59).

6. Save Button

The SAVE button is used to save a Complete R&S Plan to a file. When this button is pushed, a type-in window appears that allows a file name to be assigned to the R&S Plan. This function has not been implemented.

7. Load Button

The LOAD button is used to load a R&S Plan from memory in to the R&S Planning Tool. This function has not been implemented.

8. R&S Plan Menu

The R&S PLAN MENU has functions that are already defined in the Main Menu. The only difference is the QUIT option. The QUIT option exits the Create R&S Plan Loop and returns the control to the Display Loop. For the other functions See "MENU SELECTION DESCRIPTIONS" on page 52.

J. SPECIAL KEYS

The following keyboard key are reserved for special functions:

- LEFTARROWKEY and PAD4 (Turns the driven vehicle left.)

- RIGHTARROWKEY and PAD6(Turns the driven vehicle right.)
- UPARROWKEY (Increases the speed of the driven vehicle.)
- DOWNARROWKEY (Decreases the speed of the driven vehicle.)
- PAD5 (Stops the driven Vehicle.)
- PAD8 (Make the driven vehicle look up.)
- PAD2 (Makes the driven vehicle look down.)
- PAD9 (Increases the elevation of the driven vehicle.)
- PAD3 (Decreases the elevation of the driven vehicles)

These keys only control reconnaissance vehicles. vehicles imported via the network can not be controlled. The limits assigned to these keys are limited to the capabilities of the reconnaissance asset.

APPENDIX B. SAMPLE DATA FILE

```
;; col1 time
;; col2 #BMP'
;; col3 #TANKS's
;; col4 #SP122's
;; col5 #ZSU23-4's
;; col6 #SA9/13's
;; col7 #BRDM-2's
;; col8 #BTR-60's
;; col9 #CRANES
;; col10 #CRANE SHOVELS
;; col11 #DUMP TRUCKS
;; col12 #BRIDGES
;; col13 #DITCHING MACHINES
;; col14 #BULL DOZERS
;; col15 #BUCKET LOADERS
;; col16 #MINE PLOWS
;; col17 # MINE ROLLERS
```

```
(setf aol '((0030 4 1 1 2 0 0 0 0 1 0 0 1 1 3 8 3)
(0100 7 1 1 1 1 1 0 0 1 0 0 1 1 3 8 3)
(0130 7 5 0 1 2 0 0 0 0 0 0 0 1 3 8 3)
(0200 7 4 0 1 2 1 1 0 1 0 0 1 1 3 8 3)
(0230 3 0 0 0 1 0 0 0 1 0 0 1 0 3 8 3)
(0300 13 1 0 0 1 1 0 0 1 0 0 1 1 3 8 3)
(0330 13 1 0 0 0 0 0 0 0 0 0 0 1 3 8 3)
(0400 14 1 0 0 0 2 0 0 1 0 0 0 1 3 8 3)
(0430 14 0 0 0 0 0 0 0 1 0 0 0 1 3 8 3)
(0500 30 8 0 1 0 0 0 0 1 0 0 1 1 2 8 3)
(0530 48 15 6 2 0 0 0 0 1 0 0 0 1 4 8 3)
(0600 59 22 6 3 1 6 0 1 0 0 0 1 1 4 8 3)
(0630 84 27 6 2 1 6 1 1 0 0 0 1 1 2 8 3)
(0700 93 32 11 0 1 8 0 1 1 0 0 1 1 4 8 3)
(0730 106 29 18 0 0 8 1 1 1 0 0 1 1 4 8 3)
(0800 104 29 18 0 0 7 0 0 0 0 0 1 1 3 8 3)
(0830 99 28 18 0 0 6 0 0 0 0 0 1 1 2 8 3)
(0900 97 27 18 1 1 9 0 0 0 0 0 0 1 2 8 3)
(0930 93 27 18 0 0 9 0 0 0 0 0 0 1 2 8 3)
(1000 82 27 18 1 1 6 0 0 0 0 0 0 1 2 8 3)
(1030 78 25 18 0 0 6 0 0 0 0 0 0 1 2 8 3)
(1100 79 25 18 1 0 1 0 0 0 0 0 0 1 2 8 3)
(1130 69 24 18 2 0 0 0 0 0 0 0 0 0 2 8 3)
(1200 107 27 18 1 1 3 0 0 0 0 0 1 1 2 8 3)
(1230 107 25 18 1 1 3 0 0 0 0 0 1 1 1 8 3)
(1300 105 23 18 1 2 1 0 0 0 0 0 1 1 2 8 3)
(1330 99 22 18 0 2 0 0 0 0 0 0 0 1 3 8 3)
(1400 87 21 18 0 1 0 0 0 0 0 0 1 1 3 8 3))
```

(1430 75 21 18 00000000011383)
 (1500 75 21 17 11200000011283)
 (1530 57 17 17 10330000010083)
 (1600 46 23 17 11310000011383)
 (1630 46 17 17 11310000011383)
 (1700 46 17 17 11310000011383)
 (1730 45 17 17 01600000011383)
 (1800 24 15 17 00600000011383)
 (1830 24 14 17 00300000011383)
 (1900 12 8 6 10 200000000083)
 (1930 12 16 10 200000000083)
 (2000 12 16 10 200000000083)
 (2030 9 16 10 100000011083)
 (2100 6 10 0 1100000011083)
 (2130 8 10 20000000101083)
 (2200 8 0 0 2010000011083)
 (2230 9 0 0 1100000010483)
 (2300 9 0 0 0 210000001483)
 (2330 8 1 0 0 100000001483)
 (2400 7 0 0 10 10000001483))

(setf gsr1 '((0030 0 0 0 0 0 0 0 0 1 0 0 1 1 1 0 0)
 (0100 0 0 0 0 0 1 0 0 1 0 0 1 1 1 0 0)
 (0130 0 4 0 0 0 0 0 0 0 0 0 0 1 1 0 0)
 (0200 0 4 0 0 0 1 1 0 1 0 0 1 1 1 0 0)
 (0230 0 0 0 0 0 0 0 0 1 0 0 1 0 2 0 0)
 (0300 0 0 0 0 0 1 0 0 1 0 0 1 1 2 0 0)
 (0330 0 0 0 0 0 0 0 0 0 0 0 0 1 2 0 0)
 (0400 3 0 0 0 0 2 0 0 1 0 0 0 1 2 0 0)
 (0430 0 0 0 0 0 0 0 0 1 0 0 0 1 1 0 0)
 (0500 0 0 0 0 0 0 0 0 1 0 0 1 0 0 0 0)
 (0530 4 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0)
 (0600 12 2 0 1 1 6 0 1 0 0 0 1 0 0 0 0)
 (0630 32 4 0 0 0 6 1 1 0 0 0 1 0 0 0 0)
 (0700 29 4 0 0 0 5 0 1 1 0 0 1 0 0 0 0)
 (0730 32 4 0 0 0 6 1 1 1 0 0 1 0 0 0 0)
 (0800 29 4 0 0 0 5 0 0 0 0 0 1 0 0 0 0)
 (0830 27 3 0 0 0 3 0 0 0 0 0 1 0 0 0 0)
 (0900 39 4 0 1 1 6 0 0 0 0 0 0 0 0 0 0)
 (1030 35 4 0 0 0 6 0 0 0 0 0 0 0 0 0 0)
 (1100 35 5 0 0 0 1 0 0 0 0 0 0 0 0 0 0)
 (1130 35 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
 (1200 35 7 0 0 0 0 0 0 0 0 0 1 0 0 0 0)
 (1230 35 2 0 0 0 0 0 0 0 0 0 1 0 0 0 0)
 (1300 24 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0)
 (1330 24 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
 (1400 24 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
 (1430 24 2 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
 (1500 24 4 0 1 1 2 0 0 0 0 0 0 0 0 0 0)
 (1530 24 2 0 0 0 3 3 0 0 0 0 0 0 0 0 0))

```

(1600 24 4 0 1 1 3 1 0 0 0 0 0 0 0 0)
(1630 24 4 0 1 1 3 1 0 0 0 0 0 0 0 0)
(1700 24 4 0 1 1 3 1 0 0 0 0 0 0 0 0)
(1730 35 4 0 0 0 3 0 0 0 0 0 0 0 0 0)
(1800 12 2 0 0 0 3 0 0 0 0 0 0 0 0 0)
(1830 12 2 0 0 0 0 0 0 0 0 0 0 0 0 0)
(1900 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(1930 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2000 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2030 3 0 0 0 0 1 0 0 0 0 0 0 0 0 0)
(2100 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0)
(2130 3 1 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2200 5 0 0 0 0 1 0 0 0 0 0 0 0 0 0)
(2230 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2300 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0)
(2330 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2400 3 0 0 0 0 1 0 0 0 0 0 0 0 0 0)))

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(setf rpv2 '((0030 1 0 0 1 0 0 0 0 0 0 0 0 2 0 0)

```

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(0100 4 0 0 0 1 0 0 0 0 0 0 0 0 2 0 0)
(0130 4 0 0 0 1 0 0 0 0 0 0 0 0 2 0 0)
(0200 4 0 0 0 1 0 0 0 0 0 0 0 0 2 0 0)
(0230 4 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0)
(0300 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0)
(0330 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0)
(0400 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0)
(0430 1 1 0 0 0 0 0 0 0 0 0 0 0 0 2 0 0)
(0500 2 1 0 0 1 0 0 0 0 0 0 0 0 0 1 2 0 0)
(0530 3 5 0 0 1 0 0 0 0 0 0 0 0 0 1 2 0 0)
(0600 3 5 4 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0)
(0630 4 0 4 0 0 1 1 0 0 0 0 0 0 0 1 2 0 0)
(0700 4 0 4 0 0 0 3 0 0 0 0 0 0 0 1 2 0 0)
(0730 3 5 4 0 0 0 2 0 0 0 0 0 0 0 1 2 0 0)
(0800 3 6 4 0 0 0 2 0 0 0 0 0 0 0 1 2 0 0)
(0830 3 6 4 0 0 0 3 0 0 0 0 0 0 0 1 1 0 0)
(0900 2 5 4 0 0 0 3 0 0 0 0 0 0 0 1 1 0 0)
(0930 2 5 4 0 0 0 3 0 0 0 0 0 0 0 1 1 0 0)
(1000 1 0 4 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0)
(1030 1 0 4 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0)
(1100 1 0 4 0 1 0 0 0 0 0 0 0 0 0 1 1 0 0)
(1130 1 0 4 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0)
(1200 3 3 4 0 0 1 3 0 0 0 0 0 0 0 1 1 0 0)
(1230 3 3 4 0 0 1 3 0 0 0 0 0 0 0 1 1 0 0)
(1300 4 2 4 0 0 1 1 0 0 0 0 0 0 0 1 2 0 0)
(1330 4 2 4 0 0 0 0 0 0 0 0 0 0 0 1 2 0 0)
(1400 3 9 4 0 0 0 0 0 0 0 0 0 0 0 1 1 2 0 0)
(1430 3 9 4 0 0 0 0 0 0 0 0 0 0 0 1 1 2 0 0)
(1500 3 9 4 0 0 0 0 0 0 0 0 0 0 0 1 1 2 0 0)
(1530 2 1 4 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0)
(1600 1 3 4 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0)

```

(1630 13 4 0 0 1 0 0 0 0 0 0 1 0 0 0 0)
(1700 10 4 0 0 1 1 0 0 0 0 0 1 0 0 0 0)
(1730 1 4 0 0 1 3 0 0 0 0 0 0 1 0 0 0 0)
(1800 3 4 0 0 0 3 0 0 0 0 0 0 1 0 0 0 0)
(1830 3 4 0 0 0 3 0 0 0 0 0 0 1 0 0 0 0)
(1900 3 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0)
(1930 3 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0)
(2000 3 0 0 0 0 2 0 0 0 0 0 0 0 0 0 0 0)
(2030 3 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0)
(2100 2 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0)
(2130 2 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0)
(2200 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2230 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0)
(2300 3 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2330 5 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)
(2400 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0)))

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